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The **International Food Policy Research Institute** (IFPRI) was established in 1975 to identify and analyse alternative national and international strategies and policies for meeting food needs in the world, with particular emphasis on low-income countries and on the poorer groups in those countries.

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Assessment of

Agricultural Research Priorities:

An International Perspective

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Foreword

Assessing priorities is difficult and uncertain in any context, particularly in the context of agricultural research. However, if there is to be effective use of scarce research resources, particularly in the public sector, it is not enough simply to leave the hard choices to individual scientists. Decisions about resource allocations have to be related not only to scientific possibilities but to national priorities within the broader policy setting. Thus there must be a dynamic and informed approach to resource allocations.

In the past, research managers have been forced to rely largely on informed scientific opinion and simple statistical 'congruences' in making their choices. Only recently have economists begun to focus on the problem through the development of methods whereby objective and subjective information can be brought to bear simultaneously on the issue. This monograph reports some of this work. It outlines a rigorous model that is applied to available data to derive a set of indicators of the consequences of competing research resource allocation decisions for commodities within a regional framework. It offers novel techniques for quantifying the opportunity cost of alternative research strategies and allows policymakers to explore the distributive consequences of successful research through identifying who benefits among producers, consumers, importers, exporters and ecological and geographical regions. The model described is a means to facilitate informed and, hopefully, desirable trends in agricultural research resource utilisation. It is not a substitute for resource allocation decisions involving intuitive scientific judgments of researchers and research administrators, particularly at the project level.

Because the model is innovative and embodies concepts that have not previously been applied to determining priorities for agricultural research, we anticipate further refinements as it is applied in the field. ACIAR and IFPRI share the satisfaction of bringing this research collaboration to fruition. It is also important to note that IFPRI and ACIAR are extending the analysis to twelve additional commodities, the results of which will be published at a future date.

Both institutions are committed to advancing the course of agricultural development by exploring and promoting policies that improve the welfare of people in the Third World. The ability to make correct decisions in agricultural research is critical to this process. We hope the contents of this report will be of interest and value to policymakers and research administrators in international agencies, as well as to national planning and agricultural research institutions who wish to increase the probability of supporting effective research.

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We would like to thank Joe Remenyi for his part in coordinating the finalisation of this document and for his encouragement and support at various stages. Geoff Edwards, Robert Evenson, Robert Lindner, Vernon Ruttan and Grant Scobie, all made important comments and suggestions which improved the scope of the work and the clarity of the presentation. In particular Robert Evenson's comments on the estimation of spillover effects resulted in an improved specification of this concept.

Finally the encouragement provided by Jim McWilliam through his enthusiastic support for the project in its early stages and also as it progressed, has been an important ingredient in its success. Of course, as usual the authors alone take responsibility for any shortcomings which may remain.

Abstract

A framework is developed to assist economic planners and research administrators in making choices about priorities in the allocation of agricultural research resources. A multi-regional international trade model using concepts of economic surplus is employed to derive *ex ante* measures of the relative economic benefits of alternative commodity and regional research portfolios and the distribution of these benefits among consumers, producers, importers and exporters.

The measures derived require both objective data (e.g. production, consumption, trade values, elasticities of supply and demand, prices and exchange rates) and subjective scientific judgments. The use of subjective judgments to define research domains for different commodities based on agroclimatic considerations is described. Research domains are required to assess the likely extent of spillover effects of commodity research to environments similar to those where research is being envisaged. These spillover effects are explicitly considered in estimating economic benefits. It is shown how joint decisions about commodity and regional allocations are facilitated by being able to measure potential research spillover using the methodology.

The framework enables judgments about the relative strength of research and extension systems and rural infrastructures to be factored into the analysis to suitably adjust both the probabilities of success of alternative commodity and regional research choices, and the likely ceiling levels of adoption by farmers.

Formulae are presented which integrate the above considerations in a manner which enables them to be used by managers in both national and international agencies responsible for making decisions about research priorities at the commodity and regional levels. A Fortran computer program is provided in an appendix to enable the formulae to be made operational on a microcomputer.

The framework is used to examine the implications of research which generates cost savings of 5% on each unit of production of twelve major commodities: rice, wheat, bananas/plantains, sugar, sweet potato, potato, pulses, groundnuts, sheep/goats, maize, coconuts and sorghum. The empirical analysis is conducted at an international level and includes all major producing and consuming regions of the world. Relatively homogeneous research domains are defined for each commodity using, where available, the FAO agroecological zoning studies and alternative methods when they are not. Homogeneity is first defined on this basis and further regional subdivision occurs where major differences in geography, rural infrastructure and current research intensity suggest a lack of homogeneity in probabilities of research success and ceiling levels of technology adoption.

The IFPRI data base on production and consumption has been employed along with suggested market parameters from the literature to derive quantitative estimates of economic benefits and their distribution amongst developing and developed country producers and consumers of the twelve commodities.

The empirical results of the study indicate that the highest expected returns to research investment are in rice — more than twice that for the

second and third ranked commodities, potato and wheat. Research on bananas/plantains, sweet potato, coconuts and groundnuts offer developing country producers and consumers a larger share of the expected economic benefits than any of the other eight commodities. However, this more equitable result would be achieved at a substantial opportunity cost in terms of foregone total international economic benefits from research investments in rice, potato and wheat.

Spillover effects from regions where research is conducted to other regions with similar agroecologies and rural infrastructures ranged from 64 to 82% of total international benefits, depending on the commodity. This suggests that national agricultural research systems may be collectively underinvesting in agricultural research as, in general, they would not factor research spillover externalities into their research resource planning exercises. There is therefore a complementary role to be played by multilateral and bilateral agencies supporting agricultural research since they are in a position to take potential research spillovers explicitly into account in their assessments. The research priorities evaluation framework presented in this report provides a method for this to be done.

1. Introduction

EXTERNAL support for public sector agricultural research in developing countries has increased substantially in the last 15 years, both from bilateral and multilateral sources. With this trend the need has arisen for assessment of the benefits and costs of this funding. A wide variety of criteria and approaches has been employed by international agencies involved in support for agricultural research in developing countries, including the congruence technique, assessment of impacts on human nutrition and eclectic approaches. As the Consulative Group on International Agricultural Research (CGIAR) discussions on priorities have shown, no method has proved entirely satisfactory as a means of guiding the allocation of resources to international agricultural research, and the need for further research in this field of research planning and management has been stressed.

In this study an economic surplus approach to the assessment of commodity and regional priorities for international support of agricultural research in developing countries is described and employed in an empirical analysis. The initial rationale for the exercise was to assist the Australian Centre for International Agricultural Research (ACIAR) in formulating its programs. ACIAR was established in 1982 as part of the Australian aid program with the objective of encouraging and supporting research into the agricultural problems of developing countries in fields in which Australia has special competence (ACIAR 1985). In fulfilling its mandate aimed at identifying important problems facing developing countries, it was decided to initiate this collaborative study with the International Food Policy Research Institute (IFPRI).

The partnership approach of ACIAR led to the notion of developing the priority framework in a manner which explicitly capitalises on the complementarities which might be exploited among Australia's scientists and their colleagues in developing countries. Novel approaches have been used in the study to achieve this, as well as to assess the likely spillover effects of research undertaken in one region to others with similar agroclimates and institutional infrastructure. The method is one which other national and international agencies could adapt and use, as is the model generally. Details of the formulae derived to assess priorities are presented in the paper, along with the Fortran computer program used for computations.

The methodology and empirical analysis described here do not provide a panacea for determining agricultural research priorities. However the authors contend that they provide essential information on both the likely economic benefits and distributive implications of alternative research strategies. The latter are restricted to consideration of the consumer/producer and interregional distribution of the benefits of research applied to twelve important and widely distributed agricultural commodities. Work is continuing to extend the analysis to another twelve key commodities.

2. Framework for Priority Assessment

2.1 Previous Approaches

Studies which have been undertaken to assess ex ante agricultural research priorities at the more aggregative regional or national levels in developing countries have used a large and diverse array of approaches. They have included those employing criteria which allude to equity or distributive concerns such as human nutritional status and the contribution of different commodities to its improvement, per capita incomes, the extent of food insecurity, commodity contribution to exports, etc. (Fishel 1971; Pineiro 1984; Oram and Bindlish 1983; Pinstrup-Andersen et al. 1976; von Oppen and Ryan 1985; Binswanger and Ryan 1977). Others have focused more upon efficiency criteria such as the congruence between the intensity of research efforts on particular commodities or regions and their relative importance. Scobie (1984, p. 35) provides a review of some of these studies which often use an index of the congruence between research intensities and the relative importance of commodities suggested by Boyce and Evenson (1975) to guide research resource allocation decisions.

Recent refinements to this approach suggested by Longmire and Winkelmann (1985) incorporate the notion of comparative advantage using domestic resource cost analysis to assess the likely economic value of research on different commodities and in various regions. The technique explicitly accounts for differential effects of national policies on commodities and regions, and can accommodate considerations such as food security and income distribution.

Until recently, approaches which have employed concepts of economic surplus to examine research priorities have been restricted to national research assessments where only the prospective benefits to the individual country are considered. Recent reviews of this literature include Schuh and Tollini (1979), Norton and Davis (1981), Ruttan (1982) and Anderson and Parton (1983). A common theme that emerges from these studies is the high costs involved in undertaking analyses of priorities using sophisticated optimisation routines, such as proposed by Pinstrup-Anderson and Franklin (1977). These are generally excessively demanding of data and scientific resources, both especially scarce in developing countries. They also tend to minimise the extent of scientific subjectivity which of necessity is required to properly establish even aggregate research priorities, not to mention project priorities (Shumway 1980).

During the past 15 years there has been a dramatic increase in the extent of external support for national agricultural research in developing countries. This has occurred along with substantial increases in domestic investments in agricultural research in these countries. Oram and Bindlish (1983, p. 3, 29–34) estimate that external funding increased threefold between 1971 and 1980, or at an annual compound growth rate of more than 13%. This compares with a growth rate of around 9% per year for total research expenditure in developing countries during the same period. By 1980 external assistance to national agricultural research had risen to about 40% of the total, up from 20% in 1971.

National research systems presumably assess priorities from the perspective of maximising the benefits which might accrue to the whole nation or to specific groups within it. Their decisions would not be influenced by the likely size of the benefits which might accrue to other countries as a result of research spillover effects to regions with agroclimatic and/or socioeconomic similarities. Furthermore, individual countries may decide to 'borrow' as much as possible from others. Thus, in making research resource allocation decisions individual countries, for both of the above reasons, may tend to underinvest, particularly when viewed from an international perspective. The high historical rates of return to national agricultural research investments, commonly in excess of 30% per annum (Ruttan 1982), suggest that if these possible spillover benefits are also taken into account, quite substantial underinvestment may have occurred.

International research support, whether bilateral, regional or multilateral, can be designed both to complement national research activities and to generate maximum international rather than just individual national research benefits. This can be achieved by explicitly considering the likely extent of spillover benefits among countries with similar agroclimatic and socioeconomic environments when selecting research support portfolios.

This study develops a methodology to enable intercountry or interregional spillover effects to be explicitly incorporated into an ex ante analysis of aggregate commodity and regional priorities in agricultural research, using techniques of economic surplus couched in an international trade model. The framework allows differential probabilities of research success and ceiling adoption levels amongst commodities and regions to condition the expected economic benefits from alternative strategies. In this manner Scobie's (1979) notion of research production functions is implicitly incorporated into the analysis, although not in the precise form he used. Also, both efficiency and distributive considerations are addressed.

2.2 A Partial Equilibrium Trade Model for Agricultural Research Evaluation

The model developed for the present analysis is an extension of that of Edwards and Freebairn (1981, 1982, 1984). The major extension adopted here is from a two-country to a multi-country model. This extension leads to: more detailed and comprehensive specification of spillover effects; emphasis on the capabilities of research systems in developing countries and therefore the probability of these systems achieving successful research output; and likely differences in the ceiling levels of adoption of research results in different countries.

To illustrate the basic features of the extended model, it is useful to initially use the Edwards and Freebairn two-country model. This model was developed to allow for research spillover effects to be transmitted in two ways:

(i) when research in a significant producing country (or region) so shifts world supply directly as to affect world prices; and

(ii) when in addition to or instead of (i), research in one country (or region) has relevance in others such that their supply schedules also are affected, thus lowering domestic and/or world prices.

The first scenario in the model where world price changes are the only source of spillover effects to other countries or regions is illustrated in Fig. 2.1. We have an exporting country (A) and an importing country (B) represented in the figure with their domestic demand (D_a, D_b) and supply (S_a, S_b) schedules generating excess demand (*ED*) and supply (*ES*) schedules in a world market (Fig. 2.1b). *ED* is the quantity consumers in country B would be prepared to buy in excess of that supplied by their domestic producers (S_b) at prices below the equilibrium closed-economy price (P_I) represented by the intersection of D_b and S_b. It is calculated as the horizontal distance $D_b - S_b$ in Fig. 2.1(c). *ES* represents the quantity available for

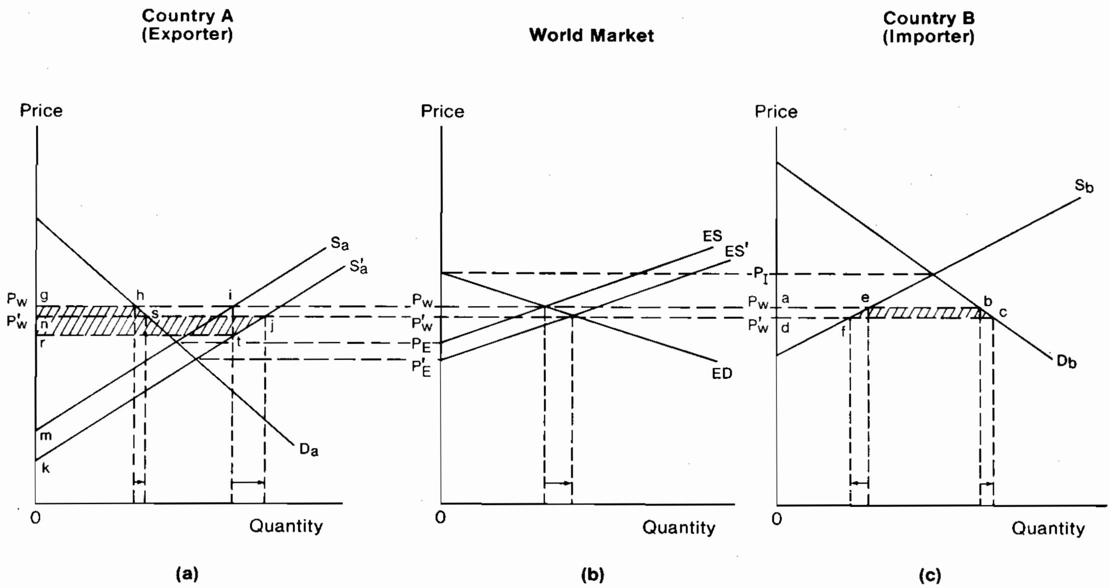

Fig. 2.1. Two-country model — no spillover research effects.

export by country A at each world price above the closed-economy price P_E. This is measured as $S_a - D_a$ in Fig. 2.1(a). The intersection of *ED* and *ES* on the world market determines the equilibrium world price, P_W and the quantity exported by country A and imported by country B. Under assumptions of no transport costs nor distortions to prices from tariffs, subsidies, taxes or quotas, P_W is also the domestic price in each country and therefore determines the quantities produced and consumed in each country.

Agricultural research in country A has the same impact on the supply of the commodity as in a closed-economy case. Here the supply schedule is shown to shift from S_a to S_a'. This shift in supply results in a shift in the excess supply in the world market from *ES* to *ES′*. The ultimate result is a fall in the equilibrium world price from P_W to P_W', which is accompanied by increased exports, and therefore imports, increased consumption in both countries, increased production in country A but a reduction in production in country B. These changes are shown by the arrows in all sections of Fig. 2.1.

The total social benefits to research are measured as the shaded areas in Fig. 2.1(a) and (c). Consumers in both country A and B benefit due to reduced domestic prices. Notice that because of the assumed relative consumption patterns, consumers in country B receive a larger share of the total benefits than those in country A. That is, the area 'abcd' is larger than the area 'ghsn'. Producers in country A gain by the difference in the two producer surplus triangles. That is, the area 'njk–gim' which is the same as the area 'njtr'. However, producers in country B lose as a result of research in country A. This is because their production costs do not change but the price of their output falls. The change in producer surplus in country B is readily seen to be negative in Fig. 2.1(c); that is, the area 'aefd'.

If the objective of research resource allocators in country A is to maximise total national benefits from research, then priority assessments will be made on the basis of the sum of the change in producer and consumer surplus in that country only: that is, the shaded area in Fig. 2.1 (a).

Alternatively, if the object of funding agricultural research is to maximise the benefits one particular group receives, then priorities may be substantially influenced by trade possibilities. This is best illustrated if it is assumed that the target group is 'consumers' in country A. In general the larger the proportion of production exported and the flatter (more elastic) domestic demand, the smaller is the share of total research benefits received by domestic consumers. If 'domestic consumers' are a group common to several commodities it is possible that research associated with a commodity with a steeper (more inelastic) demand and no exports will result in more benefits to consumers than research as illustrated in Fig. 2.1, even if total benefits in the non-traded good are substantially less than for the traded good.

The situation where research is applicable to country B production as well as country A is illustrated in Fig. 2.2. Here the exporting country, that is Fig. 2.2(a), is the same as in the previous example. Therefore the original and post-research excess supply in Fig. 2.2(b) is the same. However, now it is assumed that research undertaken in country A is partially applicable to production in country B. This spillover effect of research to country B is represented by a shift in the supply schedule from S_b to S'_b in Fig. 2.2(c). In this example the unit cost saving effect measured by 'k_{ba}' is assumed to be approximately one half the effect in the country undertaking the research, that is, 'k_{aa}'. The initial impact of this spillover effect is a shift in country B's excess demand in the world market from *ED* to *ED′*.

The result of this additional effect of research is to reduce the world price further than in the case of no spillover research effects in Fig. 2.1. There is now an increase in production in both countries, although this result only applies for the supply and demand conditions and size of spillover effect assumed in this illustration. Consumption in both countries is also increased. While total exports (and therefore imports) increase, this is not as large as in the case of no research spillovers.

The total benefits of research effort in country A are now the sum of the shaded area in Fig. 2.2(a) plus the shaded area in Fig. 2.2(c). Although clearly not the case in the illustration used here, it is possible that the benefits in country B exceed those in country A despite a lower per unit cost impact of research in the former. This could occur if country B, despite being an importer, was still a major producer of the commodity and that its production was substantially larger than the total production of country A.

Consumers in both countries gain and, because of the larger price fall, receive an increased share of the total benefits. Similarly, producers in country A gain but, because of the extra reduction in world price caused by a reduced world market (excess) demand from B, receive a reduced share of total benefits. Producers in country B, however, now stand to gain rather than lose due to research. This gain need not necessarily occur since with certain values of 'k_{ba}' relative to 'k_{aa}' and different supply and demand conditions these producers could in fact still lose from research in country A.

When this model is extended to a multi-country situation with several exporters and importers,

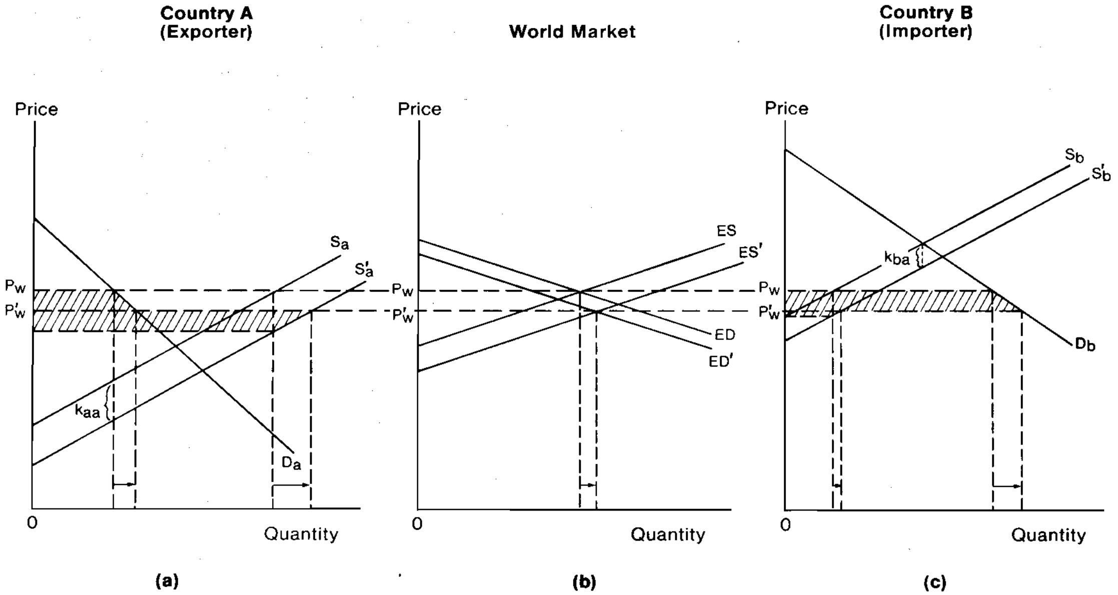

Fig. 2.2. Two-country model — with spillover research effects.

then the above implications still hold but there is scope for a large number of possible outcomes. Research spillover effects, that is 'k_{ba}', may be zero for some exporters and importers thus resulting in differences between national and global total benefit estimates and also differences in the distribution of these total benefits between consumer and producer groups in different countries.

If likely spillover effects are to be incorporated into the assessment of research priorities there are added dimensions which must be built into the analysis which do not feature in closed economy models:

(i) supply and demand conditions in other producing and consuming countries to the one where the research is to be conducted;

(ii) estimates of the size of spillover effect 'k_{ba}' relative to the size of the direct effect, 'k_{aa}';

(iii) the differentials in probabilities of success, adoption levels, and research lags among candidate countries and commodities.

The last two dimensions become increasingly important if a multi-country situation is appropriate.

2.3 Developing Algebraic Formulae to Assess Research Benefits

The model described in the previous section is partial equilibrium in nature in that resultant changes in quantities produced are assumed not to affect the prices of other commodities or services nor macroeconomic variables such as exchange rates, employment, etc. With the additional assumptions of linear demand and supply schedules and parallel shifts in supply schedules resulting from research, algebraic formulae can be derived to measure the shaded areas in Fig. 2.1 and 2.2. Derivation of these formulae for one time period and a multi-country traded situation is presented in Appendix A. For the applications of interest in this study several further extensions are important. These include allowing for different probabilities of success of research undertaken in different countries, different levels of ultimate adoption of research results, lags in the availability of research results and adoption, and the possibility that some commodities like potatoes are internationally traded in some countries but not in other countries.

For research influencing a particular commodity and undertaken in a particular country or region, the formulae with all these adjustments can be summarised as follows:

Gross International Benefits from Research Undertaken in Country 'y' on a Particular Commodity

$$E[PV(G^{y}_{w})] = \sum_{t=1}^{T} \sum_{f=1}^{n} \frac{p_{yt} x_{ft} k_{fy}}{e_{ft}(1+r)^t} Q_{sft}$$

$$+ \sum_{t=1}^{T} \sum_{f=1}^{n} \frac{p_{yt} \beta_f e_{ft} \left(\sum_{i=1}^{n} \beta_i x_{it} k_{iy}\right)^2}{2(1+r)^t \left(\sum_{i=1}^{n} e_{it}(\beta_i + b_i)\right)^2}$$

$$+ \sum_{t=1}^{T} \sum_{f=1}^{n} \frac{p_{yt} \beta_f e_{ft}}{2(1+r)^t} \left[\frac{x_{ft} k_{fy}}{e_{ft}} - \frac{\sum_{i=1}^{n} \beta_i x_{it} k_{iy}}{\sum_{i=1}^{n} e_{it}(\beta_i + b_i)} \right]^2$$

$$+ \sum_{t=1}^{T} \sum_{f=n+1}^{N} \frac{p_{yt} x_{ft} k_{fy}}{(1+r)^t e_{ft}} Q_{sft}$$

$$+ \sum_{t=1}^{T} \sum_{f=n+1}^{N} \frac{p_{yt} b_f \beta_f x_{ft}^2 k_{fy}^2}{2(1+r)^t e_{ft}(\beta_f + b_f)} \qquad (1)$$

where:

$E[PV(G^{W}_{y})]$ is the expected present value of total international benefits from research in a specified country 'y' on the commodity of interest summed over 't' years ($t = 1 \ldots T$).

p_{yt} is the probability of success of research undertaken in country 'y' in year 't' ($O \leq p_{yt} \leq 1$).

x_{ft} is the expected ceiling level of adoption in country 'f' in year 't' ($O \leq x_{ft} \leq 1$).[1]

k_{fy} is the cost reducing effect in country 'f' ($f = 1 \ldots N$) from research undertaken in country 'y'. For the country where the research takes place this 'k_{yy}' is the direct effect of the research; for the remaining N-1 countries producing and/or consuming the commodity the 'k_{fy}' will be the spillover effects of research. For many countries this is likely to be zero.

e_{ft} is the exchange rate in year 't' between country 'j' and the currency used as a standard measure of value.

r is the social rate of discount in real terms.

[1]Alternatively, one could insert a functional relationship between 'x_f' and time (t) such as a sigmoid curve.

Q_{sft} is the quantity of the commodity produced in country 'f' in time period 't' without research, that is, the initial equilibrium output.

b_f and b_i are the slope parameters ($\delta Q/\delta P$) of the demand function in the ith or fth country/region. Note that

$$b_i = \varepsilon_{di}[Q_{dit}/P_{it}],$$

where ε_{di} is the elasticity of demand for the commodity in country 'i' evaluated at the original equilibrium prices and quantities. Q_{dit} and P_{dit}. Note because negative signs are included in the demand specification the absolute values for these parameters are entered in the formulae.

β_f and β_i are the slope parameters ($\delta Q/\delta P$) of the supply function in the ith or fth country/region. Also note

$$\beta_i = \varepsilon_{si}[Q_{sit}/P_{it}]$$

where ε_{si} is the elasticity of supply.

N is the total number of 'homogeneous' countries/regions.

n is the number of countries/regions where the commodity of concern is produced or consumed and internationally traded. N–n is the number of countries/regions where the commodity is only traded domestically.

National Benefits for Country/Region 'f' from Research Undertaken in Country 'y': Internationally Traded Environment ($f = 1 \ldots n$)

$$E[PV(G_{yf})] = \sum_{t=1}^{T} \frac{p_{yt} x_{ft} k_{fy}}{e_{ft}(1+r)^t} Q_{sft}$$

$$+ \sum_{t=1}^{T} \frac{p_{yt}(Q_{dft} - Q_{sft}) \sum_{i=1}^{n} \beta_i x_{it} k_{iy}}{(1+r)^t \sum_{i=1}^{n} e_{it}(\beta_i + b_i)}$$

$$+ \sum_{t=1}^{T} \frac{p_{yt} b_f e_{ft} \left(\sum_{i=1}^{n} \beta_i x_{it} k_{iy}\right)^2}{2(1+r)^t \left(\sum_{i=1}^{n} e_{it}(\beta_i + b_i)\right)^2}$$

$$+ \sum_{t=1}^{T} \frac{p_{yt} \beta_f e_{ft}}{2(1+r)^t} \left[\frac{x_{ft} k_{fy}}{e_{ft}} - \frac{\sum_{i=1}^{n} \beta_i x_{it} k_{iy}}{\sum_{i=1}^{n} e_{it} (\beta_i + b_i)} \right]^2 \quad (2)$$

Consumer Benefits for Country/Region 'f' from Research Undertaken in Country 'y': Internationally Traded Environment (f = 1 . . . n)

$$E[PV(G_{cfy})] = \sum_{t=1}^{T} \frac{p_{yt} Q_{dft} \sum_{i=1}^{n} \beta_i x_{it} k_{iy}}{(1+r)^t \sum_{i=1}^{n} e_{it} (\beta_i + b_i)}$$

$$+ \sum_{t=1}^{T} \frac{p_{yt} b_f e_{ft} \left(\sum_{i=1}^{n} \beta_i x_{it} k_{iy} \right)^2}{2(1+r)^t \left[\sum_{i=1}^{n} e_{it} (\beta_i + b_{iy}) \right]^2} \quad (3)$$

Producer Benefits for Country/Region 'f' from Research Undertaken in Country 'y': Internationally Traded Environment (f = 1 . . . n)

$$E[PV(G_{gfy})] = \sum_{t=1}^{T} \frac{p_{yt} Q_{sft}}{(1+r)^t} \left[\frac{x_{ft} k_{fy}}{e_{ft}} - \frac{\sum_{i=1}^{n} \beta_i x_{it} k_{iy}}{\sum_{i=1}^{n} e_{it} (\beta_i + b_i)} \right]$$

$$+ \sum_{t=1}^{T} \frac{p_{yt} \beta_f e_{ft}}{2(1+r)^t} \left[\frac{x_{ft} k_{fy}}{e_{ft}} - \frac{\sum_{i=1}^{n} \beta_i x_{it} k_{iy}}{\sum_{i=1}^{n} e_{it} (\beta_i + b_i)} \right]^2 \quad (4)$$

National Benefits for Country/Region 'f' from Research Undertaken in Country 'y': Internationally Non-Traded Environment (f = n+1 . . . N)

$$E[PV(G_{yf})] = \sum_{t=1}^{T} \frac{p_{yt} x_{ft} k_{fy}}{e_{ft} (1+r)^t} Q_{sft}$$

$$+ \sum_{t=1}^{T} \frac{p_{yt} b_f \beta_f x_{ft}^2 k_{fy}^2}{2(1+r)^t e_{ft} (\beta_f + b_f)} \quad (5)$$

Consumer Benefits for Country/Region 'f' from Research Undertaken in Country 'y': Internationally Non-Traded Environment (f = n+1 . . . N)

$$E[PV(G_{cfy})] = \sum_{t=1}^{T} \frac{p_{yt} \beta_f x_{ft} k_{fy}}{(1+r)^t e_{ft} (\beta_f + b_f)} Q_{dft}$$

$$+ \sum_{t=1}^{T} \frac{p_{yt} b_f \beta_f^2 x_{ft}^2 k_{fy}^2}{2(1+r)^t e_{ft} (\beta_f + b_f)^2} \quad (6)$$

Producer Benefits for Country/Region 'f' from Research Undertaken in Country 'y': Internationally Non-Traded Environment (f = n+1 . . . N)

$$E[PV(G_{gfy})] = \sum_{t=1}^{T} \frac{p_{yt} b_f x_{ft} k_{fy}}{(1+r)^t e_{ft} (\beta_f + b_f)} Q_{sft}$$

$$+ \sum_{t=1}^{T} \frac{p_{yt} \beta_f b_f^2 x_{ft}^2 k_{fy}^2}{2(1+r)^t e_{ft} (\beta_f + b_f)^2} \quad (7)$$

To estimate these relationships for research undertaken in a particular country '*y*' for each commodity it is first necessary to define the appropriate set of 'homogeneous' production/consumption regions. More detail on this aspect of the study is given in Section 3. For each of these regions the following data are required.

1. QUANTITIES PRODUCED, Q_{sft}

This is the expected output in country/region '*f*' in a normal year '*t*'. Initially in the study it is assumed that this quantity remains the initial market equilibrium output level over the time period *T*, except for the effect of the research being considered.

2. QUANTITY CONSUMED, Q_{dft}

The consumption of the commodity in country/region '*f*' measured on the same basis as output. Again for this application the initial market equilibrium level of consumption is assumed to apply over the time period and consumption changes due only to research. Non-research related consumption growth can be included in the formulae if estimates of the growth rate can be provided.

3. DOMESTIC PRICE, P_{ft}

The export or import parity price of the commodity in country/region '*f*'. If prices currently faced by producers and consumers are distorted by government subsidy or tax policies, then care is required in determining the price to use.[2]

Although this price does not appear directly in the formulae it is used to estimate 'β_f' and 'b_f' along with the estimates of supply and demand elasticities. The price can also be important in specifying the monetary value of the 'k_{jy}'s.

4. ELASTICITY OF SUPPLY, ε_{sf}

It is important that the estimate of the parameter is relevant to the price and quantity information used. The supply elasticity along with the price and quantity is used to find the slope of the supply function, β_f, if an estimate of this slope is not readily available.

5. ELASTICITY OF DEMAND, ε_{df}

This information is used to estimate b_f in the same manner as discussed for β_f.

6. EXCHANGE RATE, e_{ft}

The exchange rate, e_{ft}, is the value of the particular country's currency in relation to the standard currency used to measure all benefits, for example, $US or $A.

7. DIRECT AND SPILLOVER EFFECTS OF RESEARCH, k_{fy}

The direct effect of research is the 'k_{yy}'value or cost-reducing effect of the research on the supply of the commodity in country '*y*' where the research takes place. The remaining 'k_{fy}' ($f = 1 \ldots N$-1) are subjective estimates of the spillover effects of the research; that is, the cost-reducing effect the research results have on the supply of the commodity in each of the other countries/regions.

The spillover effects of research are important factors in the mixed traded-nontraded good/multi-country framework developed for this study. Although estimates of these effects ultimately require subjective assessment in ex-ante studies, it is useful to discuss them in more detail so that a clearer appreciation of the judgment process is obtained.

The eventual total spillover effect of research can be a result of the combined effects of four types of spillover:

(i) price effects from increased production caused by reduced costs;
(ii) spillover of technology from country '*y*' which can be adopted without any research in country '*f*';
(iii) spillover of technology from country '*y*' which requires adaptive research before it is applicable in country '*f*';
(iv) spillover of scientific knowledge which ultimately enhances future research in many areas.

As is clear from the diagrammatical illustration of the model, the price-effect spillover due to increased production is incorporated using the supply and demand framework. The spillover of scientific knowledge, sometimes called basic research, is difficult to quantify. The assessment undertaken in this study does not attempt to directly measure this spillover effect. However, past spillovers of this nature will be captured in the estimates of probability of success and possibly levels of adoption.

Estimates of the spillover effects 'k_{fy}' used here attempt to capture the combined effect of type (ii) and (iii) spillovers, since it is not felt that type (ii) spillovers are very common in isolation. As is discussed in more detail in the next section, a two-stage estimation process using geoclimatically defined 'homogeneous' production regions and assessments of the strength of each country's adaptive research system are used to subjectively gauge this combined spillover effect.

Although not used in this study, it is also possible to determine 'k_{fy}' spillover effects, using

[2]The impact government subsidy or tax policies may have on research benefit evaluation is discussed in section 2.5 and Appendix B.

estimates of the expected increase in final output. This is achieved using the following relationships:[3]

$$k_{fy} = \frac{\gamma_{fy}}{\beta_f}$$

where γ_{fy} is the expected additional output in country 'f' after research in country 'y' at the pre-research output price.

In aggregate level priority assessment studies the direct effect of research will be difficult to estimate. Most studies use a specified percentage of the original price as an estimate and assume research costs are the same for all commodities therefore ignoring the cost component. This is the approach adopted in this study; however, as discussed in more detail at the end of this section, the issue of research productivity for different countries and commodities then becomes important.

8. Probability of Success, p_{yt}

It is important to differentiate research opportunities on the basis of their probability of success. This will largely depend upon:

(i) assessments of experienced and knowledgeable scientists;

(ii) the characteristics of the commodity and the regions where it is produced;

(iii) the type of research which is envisaged;

(iv) the number and ability of the research scientists to undertake the research;

(v) the structure of the research system and the facilities;

(vi) previous research which has been conducted both nationally and internationally on the issues.

In section 3 the approach used to estimate the probabilities of success at an aggregate level is described. It attempts to take the above factors into account in determining subjective estimates of these probabilities.

9. Expected Level of Adoption, x_{ft}

The expected ceiling levels of adoption of research results will depend on a number of factors. Objective quantification of all of these factors and their relationship with the decision to adopt technology is complex and beyond the scope or aims of this study. The expected ceiling level of adoption is one of the factors which is subjectively assessed for quantification. As is discussed in Section 3, information on the strength of extension services and indicators of previous high levels of adoption of new technology were used in making the necessary judgments in the present study. The importance of lags in adoption are also discussed in detail in that section.

If the technology resulting from research is not applicable to all farmers in a particular region/country or if this technology is not adopted at the same rate by all farmers, then the assumption that research causes a parallel shift in the commodity supply may not be appropriate. In such situations alternative formulae to those outlined above should be used. For a good discussion see Lindner and Jarrett (1978), Rose (1980) and Edwards and Freebairn (1982). The social benefit measures and their distribution can be significantly affected by a change in this assumption. However, if the same situation applies to all countries and all commodities then the relativities between the benefits will be much the same.

In this study considerable effort has been concentrated on defining 'homogeneous' production regions for each commodity to ensure technology will be equally applicable and the adoption levels by farmers are reasonably uniform. If the former were to apply but not the latter, then separate regions are used to represent production from each source. To the extent that this has been successfully achieved then the parallel shift assumption is acceptable. Clearly at the level of aggregation used in this study it is unlikely that perfect homogeneity will be achieved. The additional assumption required in these circumstances is that adopters and non-adopters are uniformly distributed along the supply curves. If this assumption does apply then care is still required in interpreting the distributive effects in the manner discussed in later sections. That is, non-adopters included in a region with adopters will not gain from research as the price spillover will cause them to lose. The producer gains, as estimated, will be net gains for the group.

10. Discount Rate, r

In the empirical analysis later in the paper a social discount rate of 12% is employed. Since prices used will not be adjusted for expected rates of inflation this is assumed to be the real discount rate. The choice of this rate is to a large degree arbitrary. Some will argue that real rates of return are considerably lower than the value chosen. On the other hand, others such as Fox (1985) have suggested that higher social opportunity costs of research funds are appropriate. Since similar lags are used for each commodity and country/region, only the absolute values of benefits will be affected and not the relative values. The latter are of primary interest in studies such as this.

11. Cost of Research, C_{yt}

At an aggregate assessment level it is difficult to

[3]For a discussion of this see Edwards and Freebairn (1982, p. 201).

specify these costs. In most studies the costs are assumed to be equal for the specified cost reduction effects (k_{yy}). The approach adopted here is to use broad categories of high, medium and low research cost countries. It is important if adopting this approach that such categories be consistent:

(i) across regions within a commodity group;
(ii) across commodity groups within a region; and
(iii) across regions and commodities.

2.4 Discussion of Formulae

The inclusion of the possibility of internationally traded and non-traded commodities for a large number of countries represents an extension to the Edwards and Freebairn model. In addition the probability of success of research, level of adoption by producers, different exchange rates and transport costs have also been added. As a result the formulae listed above have a number of new terms not included in those developed by Edwards and Freebairn. Despite these factors the formulae still are basically similar to those of their two-country model. Hence most of the important implications that were drawn from their model will still apply. The main change is that several of the variations discussed by Edwards and Freebairn can now all apply to different groups in different countries for research on a single commodity. For example, producers in some countries other than where research is undertaken can gain while those in other countries can lose.

The interaction between elements used to extend the framework, for example probability of success, level of adoption and the spillover effects, are readily observable by inspection of the formulae. Since all of these parameters take values between zero and one there is scope for the benefits to be significantly different from those obtained if these factors are not considered.

The introduction of transport costs between countries/regions in the form specified in this model does not directly affect the benefit estimation formulae. However, these transport costs are important indirectly since the formulae require that prices used in estimation of the 'k_{fy}'s or the supply and demand slope parameters, are based upon import or export parity. Internationally traded commodities therefore clearly involve consideration of the appropriate transport costs.

The formulae developed reemphasise the fact that even when research does not have a spillover effect on another country (i.e. $k_{fy} = 0$), there may still be benefits (or losses) to that country via the world price effect. As was emphasised by Edwards and Freebairn (1984) if distributive objectives are relevant this effect may be very important.

2.5 Some Further Considerations

The model outlined includes several features not used in previous studies. However, there are other assumptions incorporated in the model used in this study which can be relaxed. Whether these further extensions to the model are warranted will depend on the particular decision-making environment the information generated is to be used in. Several of the possibilities have been alluded to already; other possibilities include:

(i) Growth in Demand and/or Supply

The current model makes the assumption that current demand levels for each commodity in each country remain unchanged over the study period, except for changes due to the impact of research. Similarly it assumes that the supply of each commodity in each country is not expected to shift due to factors other than the research effort being considered; this is clearly not the case for all commodities for all countries. For example, population and income changes will result in shifts in relative commodity demands.

Relaxation of these assumptions is a relatively straightforward exercise in terms of adjusting the formulae. Although several specifications are possible, obtaining estimates of the shifts to include for each commodity and each country could involve a significant additional information-gathering exercise. Edwards and Freebairn (1982) included forecasts of these shifts in their two-country assessment. In this study to keep the information requirements within reason this extension was not incorporated. This will result in underestimates of benefits if expansion of demands and/or supplies is expected over the time periods considered.

(ii) Impact of Other Government Policies

The governments of a large number of countries have policies which subsidise, or in some cases tax, agricultural commodities. The framework used to provide the basis for the formulae developed above assumes such policies do not apply.

Appendix B briefly outlines the implications of government subsidies for evaluating the social benefits from agricultural research. A more detailed outline of these points is also provided by Alston et al. (1986). The main conclusion flowing from this assessment is that the formulae developed so far measure the gross private benefits from research. Included in these gross benefits is a 'social' cost component due to the increased government subsidy payments on the increased output due to research. Therefore in the case of subsidies the formulae derived earlier represent overestimates of the gross 'social' benefits from research (similarly they would underestimate these benefits in the case of net taxation of the commodity under consideration). This overestimation amounts to at least the total additional subsidy payments required.[4]

(iii) Research Productivity and Costs

An important assumption embodied in the framework is that over the range of research expenditure contemplated, research output per unit of expenditure is likely to be constant. For example, the unit cost reduction expected from investment of a specified amount of research funds would be doubled if the expenditure was doubled. For institutions such as ACIAR, which have a small research budget, this assumption of a constant marginal product of research over the range of expenditures contemplated may not be unreasonable.

To relax this assumption requires detailed knowledge of the research process; in particular information relating to what has sometimes been referred to as the 'research production function.' The research production function describes the research output that could be expected from combining different levels of 'research inputs' (e.g. research scientists, previous knowledge, equipment, etc.). In general it is reasonable to expect that, after a point, an additional unit of research output would require increasing quantities of all inputs. Heroic attempts to formulate this aspect of research output have been made (Scobie 1979). Considerably more conceptual and empirical research is required, however, before the linear assumption made in the current study can be relaxed.

Several of the factors included in the framework partially relax this assumption. Between commodities and countries the ultimate research unit cost-saving for the assumed similar level of marginal research expenditure can vary quite substantially. This is especially due to differences in the probabilities of success, levels of adoption and spillover effects assessments. As has been discussed, these factors have been adjusted to allow for such things as differences in commodity and/or country research and extension intensities. Therefore although a 5% unit cost reduction for research on all commodities in all countries is assumed to apply for a given research expenditure, once this is factored by these discounts, the eventual 'research output' will differ substantially.

[4]Additional social costs may result from the government revenue-raising activity required to make these additional subsidy payments.

3. Empirical Application of the Priorities Framework

3.1 Introduction

The primary motivation for this study was to help ACIAR assess research priorities to enable it to formulate responses to requests from developing countries for collaboration in agricultural research. ACIAR's emphasis on a partnership approach between scientists in developing countries and their counterparts in Australian research institutions suggested that an international perspective of the likely benefits from alternative research strategies was appropriate. This would need to explicitly take account of spillover effects among agroclimatically similar environments and the synergisms that could be generated by linking researchers from different developing countries and Australia.

The issues that confront an organisation such as ACIAR in formulating its priorities are similar to those that the CGIAR, The International Development Research Centre (IDRC), USAID and others face. In the ensuing section we outline an application of the model which would have relevance to these types of agencies and with suitable modifications to individual national agricultural research systems.

3.2 Steps Involved in Assembling and Utilising Data for Analysis

There are six steps which are required to make the model operational:

STEP 1

Select the commodities to be studied and assemble data by country on area, production, and consumption of those commodities.

STEP 2

Define agroclimatically homogeneous regions. This involves: defining the major climatic divisions from which significant production of the commodities under study originates, and identifying agroecological zones (AEZ), within each climatic division; tabulating the major crop/climatic associations and the countries where those associations predominate in each principal geographical region; subdividing countries by AEZ for each commodity individually and identifying the percentage distribution of each country's production (or area if not available) by AEZ; and for each commodity, grouping the countries within each major geographical region which have the bulk of their area and/or production located in closely similar agroecological zones. These groups of countries are defined for purposes of this study as 'agroclimatically homogeneous regions.'[5]

STEP 3

Estimate the probability of success of research for each commodity in each country within each of the agroclimatically homogeneous regions. If there are major differences in these probability estimates among countries in the same agroclimatic region, then this region should be divided into sub-zones to improve homogeneity.

STEP 4

Estimate the expected ceiling level of adoption of research results for countries in each homogeneous region. Again if there are major differences repeat subdivision and regrouping as in Step 3 to improve homogeneity where necessary.

STEP 5

Construct tables of the spillover effects from research undertaken in any one homogeneous region, as defined in steps 2–4, to all other regions producing the same commodity.

STEP 6

Assemble data on prices, transport costs, and price elasticities of supply and demand for each commodity.

The approach used in the present study at each step is discussed in detail in the following sections.

3.3 Selecting Commodities (Step 1)

The choice of the 24 crops and three livestock

[5]This homogeneous grouping is important for the assumption of a parallel supply shift due to research. If regions are not homogeneous with respect to all production characteristics then the parallel shift assumption may not hold. If not the formulae used here may not be appropriate and lead to under- or overestimation of the benefits. On the other hand, if all countries were affected in the same way the relative benefits would still be similar.

products shown in Table 3.1 for inclusion in the present analysis was based largely on their economic significance in terms of contribution to total gross value of agricultural production in the developing countries.[6] Also implicitly taken into account was their importance to employment and income generation on and off the farm (value added), the proportion of arable area they occupy (which in absolute terms is also a guide to the total on-farm employment they may provide), their contribution to food supply, particularly for the poor and their relevance to balance of payments. These criteria were not explicitly arrayed in a scoring system but applied simply as a screening procedure.

Most of the data on area, production, and consumption were derived from sources available at IFPRI, largely from FAO tapes. In some cases, production but not area data were available (rubber, coconut, citrus, oil palm, banana/plantain, and livestock). Consumption is derived from FAO tapes and food balance sheets and applies to all developing and developed country producers and consumers. All area, production, and consumption data are based on 1979–81 averages.

A final stage was to pool, for each commodity, under the heading of 'other developing country suppliers,' all producing countries whose average annual 1979–81 output was valued at under $US10 million. This aggregation is based on the assumption that even the most modest national adaptive research effort requires a minimum of two researchers to sustain a program. Oram and Bindlish (1981) using data from 51 developing countries, which did not include China, show average scientist person-year costs in 1980 to be approximately $US42 500 plus overheads. These costs include scientist salaries, research assistants, field and laboratory technicians, and operating costs. A subsequent calculation by the same authors covering 81 developing countries, including China, shows 1980 costs to be slightly lower, averaging $US39 000 for the larger sample. There were considerable differences between geographical regions: costs for the 33 African countries for which data are available averaging $103 000 per scientist. Thus any commodity valued at less than $US10 million is unlikely to generate sufficient funds for a research program costing about $US 100 000 a year (which would only support a single scientist in many countries); even allowing a 1% ratio of research expenditure to current product value.[7] In this situation opportunities for collaborative research with Australian or other scientists woud be limited. The small spillover benefits from research undertaken elsewhere to the country concerned are also likely to be negligible for lack of any capacity to test and adapt the research, nor can it be expected to generate research results of its own which will be of much value to other countries.

Excluding such countries reduces the total number which enter the detailed spillover analysis by about 20%, saving considerable computation. However, because their contribution to total production and to any direct or spillover benefits from research is so small, we feel that their exclusion does not introduce any significant large country bias into the analysis. A further reason for not including such producers is that many of them have a small area which is not typical of their main rainfed agroclimatic situation, or which is irrigated, which enables them to produce a limited quantity of a special crop, sometimes at abnormally high yields. Sugarcane in Africa is a good example.

3.4 Definition of Agroclimatically Homogeneous Regions (Step 2)

An innovative aspect of the approach to determining research priorities in this study is the identification of the way in which production of crops and livestock is distributed among agroecological zones. The objective of this zonation is to be able to identify the benefits of research, not only to the country or countries in which the research is actually undertaken, but also to other regions with ecological affinities, to which some of the knowledge or materials derived from research elsewhere might be relevant (spillover). Given that most of the projects which ACIAR is likely to be funding will involve collaborative research with developing countries in the tropics or subtropics, the bulk of these 'spillovers' are likely to be to other developing countries.

In this study the world was subdivided into agroecological zones (AEZ), based largely on the FAO-AEZ methodology for land suitability assessment which is now becoming widely used both regionally and nationally. FAO has published four regional studies using this approach, on Africa (FAO 1978a), Southwest Asia (FAO 1978b), Southeast Asia (FAO 1980a), and South and

[6]All commodities chosen for the analysis were assumed to be domestically traded, although all production within a country need not be. Thus at least some exchange of the commodities takes place. Most commodities are also internationally traded. Clearly the price spillover effects are influenced by whether the commodity is internationally traded.

[7]In most countries this measure of research intensity is still well below 1%.

Table 3.1. Most important crops in order of area harvested (1979–81 average) and value of production; all countries, and developing countries.

Area Harvested[1]		Value of production[8,9]		Commodities included[12]	
All countries	Developing countries[2]	All countries	Developing countries	ACIAR priorities study	FAO agro-ecological study
Wheat	Rice	Rice	Rice	X	X
Rice	Wheat	Wheat	Sugar cane	X	Partly
Maize	Maize	Maize	Banana/plantain	X	
Barley	Sorghum	Potato	Vegetables	X	
Soybean	Millet	Vegetables	Wheat	X	X
Sorghum	Cotton	Sugar cane	Maize	X	X
Millet[3]	Annual oilseeds	Cotton	Cotton	X	X
Annual oilseeds[4]	Soybean	Oranges[10]	Coffee	X	
Cotton	Barley	Banana/plantain[11]	Sweet potato	X	X
Oats	Beans	Soybean	Oranges	X	
Beans (dry)[5]	Groundnut	Barley	Cassava	X	X
Groundnut	Cassava	Tobacco	Potatoes	X	X
Potato	Sugar cane	Sweet potato	Tobacco		
Rye	Sweet potato	Coffee	Soybean	X	X
Cassava	Vegetables	Cassava	Groundnut	X	
Sugar cane	Chickpea	Sugar beet	Sorghum	X	X
Sweet potato	Coffee	Annual oilseeds	Rubber	X	
Vegetables[6]	Potato	Groundnut	Beans	X	X
Chickpea[7]	Cocoa	Sorghum	Cocoa	X	
Coffee	Tobacco	Beans	Oil Palm	X	
Grapes	Grapes	Rubber	Annual oilseeds		
Sugar beet	Peas	Cocoa	Coconut	X	
Peas (dry)	Tea	Oats	Tea		
Cocoa	Oats	Tea	Millet	X	X
Tobacco	Rye	Oil palm	Chickpea	X	

Notes on Table: Sources of data on area and production primarily 1981 FAO Production Yearbook. Prices from FAO Production and Trade Yearbooks, 1981, : calculated by IFPRI from World Bank, IMF, and other reports for the ACIAR Study.

[1] No area data available for Banana/Plantain, Coconut, Oil Palm, Oranges, other fruit, Rubber.
[2] Developing countries include Developing Market Economies countries plus Centrally Planned Asia.
[3] Millet includes all species of millet widely cultivated.
[4] Annual oilseeds comprise Rapeseed, Safflower, Sesame, Sunflower, and Linseed in aggregate.
[5] Beans include *Phaseolus* and *Vigna* species (see footnote 7).
[6] Vegetable area data are incomplete and reflect principally marketed vegetables.
[7] Chickpea includes lentils. Note that chickpeas, lentils, beans, *Vicia faba*, peas are aggregated as 'pulses' in the ACIAR study.
[8] Some commodities listed under 'area' are not listed under 'value' because they are too low in ranking.
[9] No value data available for grapes.
[10] Oranges include Oranges, Clementines, Satsumas, and Tangerines.
[11] Banana includes Plantain for which no prices are available.
[12] The ACIAR study also covers Milk Products, Beef and Buffalo Meat, Sheep and Goat Meat and Wool. The Xs refer to commodites in column 4.

Central America (FAO 1980b). These studies identify 15 major climatic divisions in the world with relevance to the developing countries. These divisions are essentially thermal zones, since they characterise the actual temperature regions during the moisture availability period. They are based on mean daily temperature classes of 5°C intervals. Four are tropical, eight subtropical, two temperate and one transitional. They are shown in the left-hand column of Table 3.2 under the heading 'Climatic Zone.'

The AEZ climatic inventory characterises both heat (temperature) and moisture conditions. This is because (providing temperature is not limiting) the time when water is available to a crop in relation to its growth cycle is critical to the

Table 3.2. Distribution of production by commodity and agroecological zone: Groundnuts, Sub-Saharan Africa (1979–81 average).

Climatic zone	Growing season zone	Zone definition	West Africa/Sahel																	
			B. Fasso Prod'n '000 MT	% of Tot	Chad Prod'n '000 MT	%	Gambia Prod'n '000 MT	%	Mali Prod'n '000 MT	%	Niger Prod'n '000 MT	%	Nigeria Prod'n '000 MT	%	Senegal Prod'n '000 MT	%	Sudan Prod'n '000 MT	%	Total Prod'n '000 MT	% of Total
Warm Tropics (Zone 1)	365 days	Warm, perennially wet tropics																		
	364–330	Warm, wet tropics											1.7							
	329–270	Warm, humid tropics											12.6	2					15.2	1
	269–210	Warm, seasonally dry tropics	3.9	6	3.5	3			1.2	1			29.2	5			15.1	2	50.6	2
	209–150	Warm, semi-arid tropics	40.8	59	81.4	83	89.7	100	51.0	35			255.4	45	352.7	51	126.3	14	997.3	37
	149– 90	Warm, semi-arid tropics	24.2	35	10.1	10			83.0	56	70.2	67	253.1	44	319.4	46	186.8	21	946.9	35
	89– 0	Warm, arid or irrig. tropics			4.3	4			11.8	8	35.2	33	20.6	4	22.2	3	561.4	63	655.8	25
TOTAL WARM TROPICS			68.9	100	99.3	100	89.7	100	147.0	100	105.4	100	572.6	100	694.3	100	889.6	100	2665.8	100
Cool Tropics or tropical highlands (Zone 2–3)		(Not applicable to these countries)																		
Cold Tropics (Zone 4)		"																		
Warm subtropics (summer rainfall) (Zone 5–7)		"																		
Cool subtropics (summer rainfall) (Zone 8–9)		"																		
Cold subtropics (summer rainfall) (Zone 10)		"																		
Subtropics (winter rainfall) (Zone 11)		"																		
Cold subtropics (winter rainfall) (Zone 12)		"																		
Cool/cold temperate (Zone 13–14)		"																		
Transitional* (Zone 15)		"																		

* This is an intermediate zone between two zones of the warm and cooler summer rainfall subtropics, where moisture distribution permits cultivation in two different major climates at different times of the year. Due to the effects of latitude and altitude the warm subtropics in parts of Brazil, Argentina and Uruguay become significantly cooler in this zone, moving southwards. Only in this region of the world is this recorded by FAO as a separate Transitional Zone between the warm and more moderately cool subtropics.

determination of its suitability to a given area, as well as to the assessment of agroclimatically attainable yields.

In the FAO methodology quantification of moisture conditions is achieved through the concept of 'reference length of growing period,' defined as the duration in days when moisture supply (from precipitation *and* soil moisture storage) permits crop growth. This is considered to be when supply exceeds half of potential evapotranspiration. Twenty reference 'length of growing period' zones at 30-day intervals were mapped for the FAO Regional Studies. For the purposes of this study it was decided (after consultation with FAO) to reduce these to seven, as shown in column 2 of Table 3.2. These range from zones which are permanently wet (365 days) to those which are permanently arid (less than 89 days growing season) and which can hardly support a crop without supplementary water, or because cold imposes a marginal length of growing period.

Most of the length of growing period (l.g.p.) zones used for assessing spillover potential in this study are based on 60-day intervals (combining two of the FAO zones), since it is a relatively rare event at the national level for all of the area of an important crop to be concentrated in one 30-day l.g.p. zone. Only the very wet and very dry zones have different intervals (365 and 0–89 days respectively).

In order to assess the suitability of land to the production of individual crops, FAO combines the agroclimatic suitability classification described above with an agroedaphic suitability classification. The latter shows how well the conditions of each soil-terrain unit matches the requirements of each crop. This is derived from a soil resources inventory using the FAO/UNESCO soil map of the World (FAO/UNESCO, 1971–81) as the source of data. By overlaying the climatic inventory on the soil inventory FAO has produced a mapped and computerised resource inventory of climate and soil units to determine land suitability and potential yields at various levels of inputs for each crop. FAO uses its climatic inventory data to compute 'constraint-free' crop yields by thermal and l.g.p. zones. These yields are then modified according to known climate-related constraints to derive agroclimatically attainable yields by thermal and l.p.g. zone (agroclimatic suitability classification). By imposing soil and landform limitations on these yields (agroedaphic suitability classification) the final assessment is made of the extent of land suited to the production of a given crop at a specified level of inputs (land suitability classification). Four suitability classes are defined and mapped for each crop in the regional studies, i.e. very suitable, suitable, marginally suitable, and not suitable. The area of each is shown by FAO in accompanying tables.

Apart from the rather limited range of crops covered and the important omission of irrigated cropland, the main problem with the FAO studies is that they define potential suitability, and not actual land utilisation for any given crop. Thus there is a great deal of overlapping among crops. For purposes of the definition of research priorities and for the identification of spillover benefits, it is important to know the actual area currently devoted in each agroecological zone to each crop under study, if possible down to within-country regions. This involves a further complication; crop area and production statistics are usually collected and compiled by administrative units which tend to cut across, rather than correspond with, AEZ.

To solve this problem FAO has transferred data for its selected commodities from administrative units to AEZ through mapping and measurement techniques. This has been done for the majority of developing countries, and has proved very useful for purposes of this study in relation to the eleven commodities included in the FAO studies.[8]

Although the FAO/AEZ studies provide useful indicative guidelines to the probable spillover potential among agroclimatic zones even for the crops *excluded* from the FAO studies and for livestock (based on their regional maps of major climatic zones, l.g.p. zones, and land suitability potential), problems still exist in obtaining satisfactory data on the current distribution of those crops and livestock by AEZ. To help fill in this gap we have used information derived from many other sources, including: earlier climatic studies on East Africa (FAO/UNESCO/WMO 1969), the semi-arid zones of West Africa (FAO/UNESCO/WMO 1967), and the Andean region (FAO/UNESCO/WMO 1975); ICRISAT agroclimatic studies on Brazil (Reis 1978); India (Krishnan 1980); West Africa (Kassam 1976; Sivakumar et al. 1984); millet (Rachie 1975) and groundnut (Mertin 1980); sorghum and millet (IDRC 1984); data on crop distribution in China from Stone (1984) on root crops, and on wheat in cooperation with CIMMYT (Stone et al. 1985); geoclimatic maps (Huke 1982a, b) and other data on rice from

[8]The FAO Regional Studies cover eleven major crops (ten food crops and cotton). The food crops include pearl millet (*Pennisetum typhoides*), sorghum, maize, wheat, rice, soybean, beans (*Phaseolus*), sweet potato, white potato, and cassava. Those 11 crops were selected by FAO as being the most widely distributed geographically across the world, although, as can be seen from Table 3.1, they are not necessarily the 11 most important in terms of the total area they occupy or of their gross value.

IRRI (1974, 1983, 1984); from CIP (1984) on potatoes; ISNAR (1981) on the South Pacific, especially coconut.

Useful information on the distribution of livestock was obtained for sheep and goats from reports by Winrock/World Bank (1983) for developing countries generally, ILCA (1985) for Sub-Saharan Africa, and Mason (1980) for Brazil. Regional reports by Jarvis (1982) on livestock in Latin America, FAO (1972) on the Near East, and IDRC (Fine and Lattimore 1982) on Asia, also yielded valuable data.

It is important for readers of this report to understand the broad outlines of the FAO methodology because of its valuable input to spillover assessment. However, it does not seem necessary to describe it in greater detail here, since this can be found in the FAO studies referred to in the bibliography. For purposes of this study we have used primarily the FAO agroclimatic suitability classification to identify ecologically homogeneous zones for the determination of spillover effects, with particular emphasis on length of growing period; although drawing on the edaphic and land-suitability assessments for fine tuning of climatic analogies.[9]

It is necessary to bear in mind that zones with the same length of growing period can exist under quite different temperature and moisture regimes, and therefore in different/major thermal regions, depending on the factors limiting growth. These are principally rainfall (too much or too little) in the lowland tropics; and temperature, as determined by altitude and/or latitude. Thus some areas in both the tropics and the temperate zones may have a year-round growing season. Conversely, some in both thermal zones may have a very short season, although the limiting constraints in the two zones would usually be very different; also the nature and composition of the plant community would differ because of the contrasting physiological requirements of tropical and temperate species, including response to day-length.

The physiological factors which determine the phenology and productivity of most plant species are known. Depending on its physiological requirements the most suitable area for a crop may lie entirely within one major climatic division (thermal zone) such as the warm tropics; in parts of several thermal zones with a range of l.g.p. zones; for example warm wet tropics (364–300-day growing period) or cooler tropics modified by altitude (270–329-day growing period). *Within* a given agroclimatic region, soil and/or slope factors can play a key role in determining its suitability to different forms of land use and crop species.

However, some species have a much broader range of adaptability than others. Crops with relatively little plasticity restricted to the warmer and more humid regions of the tropics (and largely to the lowland areas), include yams, cocoyams, plantains, coconuts, cocoa, oil palm, and rubber. Pearl millet and cotton are grown mainly at the drier end of the rainfall spectrum, in warm tropical and subtropical regions. Wheat and potatoes (*Solanum tuberosum*) are only grown at higher altitudes in the tropics. In the case of coffee, two different species dominate production at different altitudes, mainly in the tropics; one, Canephora (*Robusta*), being confined to elevations below about 1700m; the second, *Arabica,* being found principally at higher altitudes. On the other hand, maize, sorghum, and *Phaseolus* beans have cultivars physiologically adapted to the lowland tropics, the subtropics, and to temperate regions or high altitude areas in the tropics. Consequently, they are widely distributed not only across l.g.p. zones but across thermal regions at various altitudes as well.

Thus it is the specific nature and location of a crop within a country which determines its zonal definition, and consequently the affinity it may have with other producing countries for identification of spillover potential. The latter is particularly difficult with species such as maize which are adapted to a broad range of agroecological zones.

In relation to the definition of agroclimatically homogeneous regions it is also important to recognise that few countries derive all of their production of a commodity from one, or even two, agroecological zones. Those that do tend to be at the extreme ends of the rainfall spectrum—either very wet (Malaysia, Zaire, Congo, Western Samoa) or very dry (Botswana, Somalia, Egypt, Yemen). Most others have their production emanating from several zones, although with a predominant contribution from one or two. As FAO notes in its AEZ reports, there is generally a good deal of overlapping of production between the l.g.p. bands within a major thermal zone. In some countries, especially those at the tropical margins, or where part of the cultivated area is at higher elevations, there may also be overlapping between major thermal zones. Thus, a country may derive part of its production from several l.g.p. zones in the warm tropics, and from zones with similar or

[9]Despite the considerable body of information used in defining AEZ's here, there are still alternative views on how best to define 'homogeneous' regions. A continuing aim of the study is to refine these zone definitions as this information comes to hand.

different lengths of growing period in the cooler tropics, or another major climatic zone. Ethiopia, for example, has 32% of its wheat area distributed among four l.g.p. zones in the warm tropics, 60% among five zones at higher elevations in the cooler tropics, and 8% in the cold tropics at higher altitudes still. In such circumstances definition of homogeneity is complex and requires considerable judgment. Large countries such as Brazil, China, India, Indonesia, and Nigeria, countries which cover a wide latitude band (Argentina, Chile, Cameroon, Sudan), and countries with cultivated land at many elevations (Algeria, Colombia, Kenya, Nepal, Turkey, etc), are likely to contain a diverse range of agroecological zones.

In order to avoid excessive complexity in zonation it was therefore decided to classify countries for homogeneity for a given commodity in terms of the *dominant* AEZ's from which the bulk of the production of that commodity orginates, even if in fact a small proportion comes from several others. For instance if 90% of the producing area is located in the warm semi-arid tropics, the country is defined for that commodity as being in that major climate. Within a major thermal zone the critical l.g.p. is also defined wherever it is sufficiently clear-cut, e.g. 'mainly in semi-arid tropics with a 75–120-day growing season.' However, if a significant share of production also originates in another major climate, that area is also identified in the definition, e.g., 'major area in warm tropics with 75–120-day growing season, but at least 20% in cooler tropics.' Each commodity has its own specific set of AEZ for spillover determination, and these are described in separate tables by thermal zone, as well as across thermal zones where applicable; l.g.p. zones are identified; countries included in each homogeneous AEZ are also listed. See Table 3.3 as an illustration for groundnuts.

Because of crop-specific ecological requirements the number and exact nature of the ecologically homogeneous zones defined in this study, although based on the FAO framework, is not uniformly distributed geographically, but varies with each commodity (Table 3.4 for an example for Sub-Saharan Africa). Thus the first 12 completed commodities include between them about 30 'homogeneous' zones, although no single commodity has production originating in all 30, and a number of zones appear quite infrequently, especially in the cold tropics, subtropics, and temperate climates. The bulk of agricultural production in the developing countries is located in the warm sub-humid to semi-arid tropics, and in the cooler tropics modified by altitude in Africa and Latin America.

Nevertheless, there are several large developing countries with major areas within the subtropics or temperate zones, notably Argentina, Brazil, China, India, Korea, Mexico, Chile, Pakistan, Turkey, and nearly all of the West Asia/North Africa Mediterranean winter rainfall subtropical zone. These countries, and some within the tropics with cultivated areas at higher elevations, are most likely to generate research results applicable to analogous climatic zones in developed countries, or to obtain spillover benefits from research in those countries.

3.5 Identifying the Probability of Success of Research for Each 'Homogeneous Region' (Step 3)

The unit-cost-reducing impact of research discussed in Section 2 above assumes that research objectives are fully achieved. However, there are many reasons why all research in a country will not achieve the stated objectives. In addition, there are likely to be substantial differences in the probability of success of achieving research objectives among countries and commodities due to factors such as the history of previous research and the current level of research intensity.

The expected total benefits of research are found by multiplying the total benefits by the estimated probability of success (p_{yt}) in research. This probability of success was subjectively estimated as a result of inspection of quantitative and qualitative data on national research systems for 83 countries (summarised in Table 3.5), including information on the actual number of research workers in each country for the crops and livestock commodities examined (see Table 3.6).

Although final probability of success estimates for each country were subjectively derived, the judgments used were made on the basis of a common underlying relationship between factors it is believed influence research success. The simple relationship is illustrated in Fig. 3.1. Here it is postulated that as the current intensity of research in a country increases, the probability of success of research projects changes in the manner depicted in the upper section of the Figure. At low intensity levels the probability of success is low and continues to be so over a range of intensity levels. Once current intensity reaches a certain level the probability of success is assumed to increase rapidly. Beyond a point, however, increased intensity levels have limited impact on the probability of success as it is approaching the maximum feasible level, which depends on factors other than current research intensity.

An aspect of the probability of research success that is particularly important given the collaborative nature of ACIAR research funding,

Table 3.3. Groundnut — Country groupings for spillover effects of research.

Code[1,2]		Definition	Agroclimatic zonation	Countries included in each zone[3]
AFRICA	WT 1	Warm, wet tropics	Mainly in warm, wet tropics with a 300–365-day growing season	Zaire
"	WT 2	Warm, humid tropics	Mainly in warm, humid tropics with a 270–329-day growing season	Cameroon, Sierra Leone
"	WDT 1	Warm, seasonally dry tropics	Mainly in warm, seasonally-dry tropics with a 210–299-day growing season	Angola, Central African Rep., Congo, Ivory Coast, Uganda
"	WDT 2	Warm, seasonally-dry tropics	Mainly in warm, seasonally-dry tropics with a 180–269-day growing season	Benin, Malawi
"	WDT 3	Warm, seasonally-dry tropics	Mainly in warm seasonally-dry tropics with a 180–209-day growing season	Guinea, Ghana, Togo, Zambia, Zimbabwe
"	SAT 1	Warm, semi-arid tropics	Mainly in warm, semi-arid tropics with a 150–209-day growing season	Chad, Gambia, Guinea-Bissau
"	SAT 2	Warm, semi-arid tropics	Mainly in warm, semi-arid tropics with a 120–179-day growing season	Burkina-Fasso, Mali, Mozambique, Nigeria, Senegal
"	SAT 3	Warm semi-arid/arid tropics	Mainly in warm, semi-arid to arid tropics with a 75–119-day growing season	Niger, Somalia, Sudan
"	TM 1	Tropical, modified by altitude	Mainly in warm, seasonally-dry/semi-arid tropics within a 90–269-day range, but with a small area in cooler tropics	Madagascar, Tanzania
"	TM 2	Tropical, modified by altitude	Mainly in warm, seasonally dry/semi-arid tropics with a 90–269-day range, but with over 20% in cooler tropics	Kenya
"	TM 3	Tropical, modified by altitude	Mainly in the semi-arid tropics with a 75–209-day growing season but over 50% of area in cooler tropics	Ethiopia
"	TM 4	Tropical, modified by altitude	Mainly in the seasonally-dry tropics with a 210–269-day growing season but over 70% of area in cooler tropics	Burundi, Rwanda
LATAM	WDT 3	Warm, semi-arid tropics	Mainly in warm, semi-arid tropics, with a 180–209-day growing season	Cuba, Haiti, Venezuela
"	TM 2	Tropical, modified by altitude	Mainly in warm, seasonally-dry/semi-arid tropics with a diverse range of growing seasons but with over 20% of area in cooler tropics	Dominican Rep., Bolivia
"	TM 3	Tropical, modified by altitude	Mainly semi-arid (75–149-day growing season) but with over 50% of this area in the cooler tropics or warm subtropics	Ecuador, Mexico
"	T/ST	Tropical/Subtropical	Substantial areas in both the warm tropics and the warm, humid subtropics	Brazil, Paraguay
"	STT	Subtropical/transitional	No area in tropics, substantial areas in semi-arid regions of warm and cool tropics and transititional zone	Argentina
ASIA	WT 1	Warm, wet tropics	Mainly in warm, wet tropics with a 330–365-day growing season	Malaysia
"	WT 2	Warm, humid tropics	Mainly in warm, humid tropics with a 270–329-day growing season	Bangladesh, Indonesia, Philippines
"	WDT 2	Warm, seasonally-dry tropics	Mainly in warm, seasonally-dry tropics with a 210–269-day growing season	Sri Lanka, Thailand, Vietnam
"	WDT 3	Warm, seasonally-dry tropics	Mainly in warm, seasonally-dry tropics with a 180–269-day growing season	Burma
"	SAT 2	Warm, semi-arid tropics	Mainly in warm, semi-arid tropics, with a 90–179-day growing season, but with 10% of area in warm, semi-arid subtropics	India
"	WST	Warm, subtropics	Minor area in tropics; predominantly in semi-arid, warm subtropics	Pakistan, China, Rep. Korea
WANA	MED 2	Subtropics, winter rainfall	No area in tropics; predominantly in semi-arid, winter rainfall subtropics (Mediterranean-type climate) with a 120–209-day growing season	Morocco, Syria, Turkey
"	MED 3	Subtropics, winter rainfall	Minor area in tropics, Predominantly arid Mediterranean-type climate with crop dependent on irrigation	Egypt, Libya
NAM		Subtropics, summer rainfall	Sub-humid with 180–269-day growing season	United States, Canada

Table 3.3. Groundnut — Country groupings for spillover effects of research.

Code[1,2]	Definition	Agroclimatic zonation	Countries included in each zone[3]
DEVAS	Subtropics, summer rainfall	Sub-humid with 180–269-day growing season	Japan
DEVOL	Seasonally dry tropics/ subtropics	Summer rainfall with 150–209-day growing season	Australia
DEVAFR	Warm, semi-arid subtropics, summer rainfall	Summer rainfall with 120–179-day growing season	South Africa

1 For other commodities two additional developed regions which do not produce significant quantities of groundnuts may also be included. These regions are:

WEUR: WESTERN EUROPE. This comprises 20 countries, mainly temperate, but including important areas of the subtropics (winter rainfall) in Southern Europe. The region is an important producer of wheat, sugarbeet, potatoes, corn, and meat.

CPEUR: CENTRALLY PLANNED EUROPE. This comprises eight mainly temperate countries of Europe, with some subtropical areas in southeast Europe; and the USSR. Because of its vast size, especially in Asia, the latter has ecological affinities with a number of developing regions, especially in WANA and in Asia as well as with developed regions, especially NAM and WEUR.

2 Where so little production is recorded for a developed region that is unlikely to have a significant research program on that commodity, or to capture or generate spillover benefits, its production and consumption are recorded under ODEVS (other developed suppliers), and no spillover is allowed for. Where no production at all is recorded and the region concerned is simply consuming the commodity its consumption is shown under the heading ODEVC (other developed consumers) and there is no spillover. Very small producers and non-producers within developing regions are treated similarly, but they are recorded under the headings ODINS for small producer and ODINC for non-producers consuming that commodity.

3 For other commodities other countries may be included in a region, e.g., Canada in NAM for wheat.

is the increment to the probability of success due to the Australian or other scientific input into the research environment. In Fig. 3.1 it is hypothesised that the added research input is the same as an effective increase in the research intensity of the developing country research system. Further, it is postulated that national systems with low research intensities can benefit little from collaborative research inputs. It is suggested that at moderate current research intensities, the increment due to ACIAR collaboration is likely to be greatest and subsequently declining at higher research intensities. The distance between the two curves in the top portion of Fig. 3.1 measures the ACIAR increment. Another way of arraying this incremental effect of collaborative research is shown in the lower portion of Fig. 3.1.

The probability of success of current research systems is likely to take the full probability range, that is, zero to one. However, in the application for this study it was judged that the ACIAR increment is likely to take the range zero to 0.2 for the commodities and countries analysed. An illustration of the subjective probability estimates used for groundnuts is contained in Table 3.7.

Although no bias will result in the estimation of total benefits from successful research if countries are aggregated, the *expected* total benefits will nevertheless be different depending upon where the research is undertaken. It may therefore be necessary to separate otherwise 'homogeneous' groups of countries with different probabilities of success of research into different production/ consumption regions. This has been done, how-

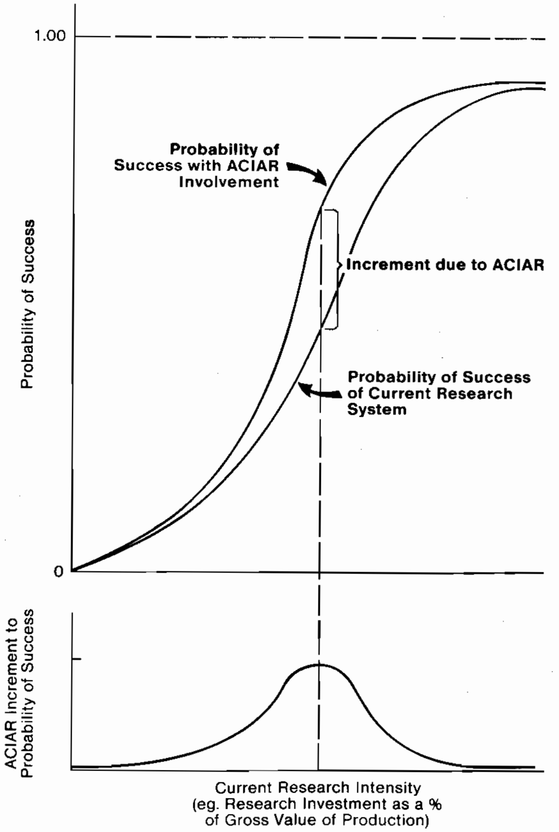

Fig. 3.1. Schematic representation of the relationship postulated between current research intensity on a commodity in national agricultural research systems and the probability of success with collaborative research.

Table 3.4. Distribution of major foodcrops in Sub-Saharan Africa (percentage share of total annual crop area) by climatic zone 1980.

	Cereals					Roots and tubers				Pulses			Annual Oilseeds			Sugar Cane or beet	Other Crops	Annual Crops as total crop area
	All Cereals	Wheat & barley	Rice	Maize	Millet & sorghum	All roots & tubers	Potato	Sweet potato	Cassava	All pulses	Dry beans	Other pulses	Groundnut	Soya beans	Other oilseeds			
Sorghum-millet: semi-arid tropics																		
Botswana	82			20	62					13			2		3			100
Burkina-Fasso	72		2	4	64	1		1		19			7		2			99
Chad	74		3	1	69	5			3	8	6		10		2			100
Gambia	43		13	6	17	1			1	6			49					100
Mali	87		7	5	72	1				2			10					100
Mauritania	60		1	5	54	3		3		34			3					98
Niger	75				74	1			1	21			3					0
Nigeria	62		3	8	51	14			6	19			3	1	1			89
Senegal	52		3	3	46					3			45					100
Somalia	84	1		24	58	1			1	3	3		2		9	1		97
Sudan	71	4		1	66	1			1	1			15		12			99
Cape Verde Islands	96		18	8	70								4					95
Maize: sub-humid tropics/subtropics																		
Lesotho	94	14		51	28					6	3	1						100
Malawi	67		2	58	7	3	2		1	16	5		13			1		99
Namibia	90	1		57	32	8				2								99
Swaziland	66		2	62	2	5	3	2		4	1		3			22		97
Zambia	90			75	14	4			4	1			2		2	1		99
Zimbabwe	84	2		57	25	1			1	2	2		8	2	1	1		96
Reunion	20			20		10	5		5	15	15					50	5	
Maize/roots: humid lowland tropics																		
Angola	68	2	2	57	8	15	1	2	12	10	10		4		2	1		66
Benin	58		1	43	12	21			13	11	10		10					69
Cameroon	45		1	24	20	29	2	1	10	8	7		16		1	1		69
Ghana	55		5	21	30	31			14	8			6			1		49
Mozambique	49		4	30	14	31			30	6			9		2	3		90
Togo	61		4	23	33	16			5	15	11		7		1			89

Rice/roots: humid coastal tropics																		
Comoro Is.	74		66	8		23	3	3	17				3					
Guinea	68		45	6	1	11		1	9	6		6	14					93
Guinea-Bissau	44		21	3	11	4				2		2	49			1		85
Ivory Coast	56		21	28	6	39		1	10	1		1	3			1		65
Liberia	63		63			29		1	27	2		2	2		2	3		56
Madagascar	71		64	7		22	2	4	16	3		3	2			2		79
Sierra Leone	81		75	2	3	6		1	4	10		10	3					79
Roots: equatorial wet tropics																		
Central African Republic	26		2	15	9	51			44	2			16		5			91
Congo	10		2	15		53		4	47	7	4	3	18		1	4		92
Equatorial Guinea	3			3		81		3	78				3			10	3	
Gabon	8			8		79		1	54				9			4		33
Sao Tome	0					30			30								70	
Zaire	28		8	19	2	52		2	49	7	4	2	12			1		87
Tropical: modified by altitude: mixed crops																		
Burundi	37	1		16	21	24	1	11	9	36	32	4	4					81
Ethiopia	77	22		17	16	6	1			13		10	1		3			90
Kenya	67	8		46	12	7	2	2	3	23			1		1	2		83
Ruanda	32	1		10	21	27	4	16	6	37	29	8	2	1				74
Tanzania	54	1	4	34	15	26	1	1	24	13	8	2	2		3	1		79
Uganda	40			11	27	26				16			10		6	1		59

Table 3.5. Summary of data on national research and extension systems by geoclimatic region used for calculating probability of success and ceiling adoption levels (83 countries for research, 57 for extension).[1,2]

Geoclimatic region and food staples	AG. GDP 1980 Mill. US $	Total No. Research Workers	Total No. Extension Workers	Research and extension workers: 10 Mill. $ AG. GDP		Farmers per Extension Worker[3]	Researchers per capita Total Pop'n	Research expenditure AG GDP/ Ratio	Cost per scientist 1980 ($)[4]
				Research	Extension				
Africa: Sub-Saharan	56 331	5 989	41 027	1.07	14.27	697	17	0.71	63 000
Semi-arid tropics: Sorghum/millet	21 787	2 584	16 217	1.19	8.85	760	20	0.87	73 323
Sub-humid tropics: Maize/pulses	2 047	654	8 736	3.20	42.68	360	31	2.46	76 588
Equatorial wet tropics: Maize/roots	17 708	884	297	0.58	48.16	1 048	11	0.30	51 354
Humid coastal tropics: Rice/roots	5 452	508	3 429	1.10	30.42	330	18	0.90	83 955
Tropics modified by altitude (mixed crops)	9 337	1 359	12 248	1.45	18.73	933	15	0.52	35 985
Latin America	83 706	10 328	20 618	1.20	2.44	1 142	29		
Sub-tropical South Amer: Wheat/rice	17 793	1 872	1 463	1.05	0.82	1 025	42		
Tropics modified by Altitude: Maize/beans	45 095	5 051	14 611	1.12	3.24	957	26		
Humid tropics Cent. Amer: Maize/beans	18 882	2 746	3 224	1.45	1.74	2 220	29		
Humid tropics Caribbean: Sugar/bananas	1 936	659	1 320	3.05	25.85	684	40		
Asia	123 481	20 866	161 169	1.69	13.05	953	17	0.33	19 800
Sub-tropical South Asia: Rice/wheat	70 009	12 206	108 970	1.74	15.56	1 030	13	0.31	17 360
Sub-tropical East Asia: Rice/wheat	11 969	1 011	14 754	0.34	12.33	360	26	0.39	45 970
Humid tropics S.E. Asia: Rice	41 503	7 649	37 445	1.84	9.02	852	28	0.37	19 860
Oceania									
Humid tropics: Coconut/roots	1 222	184	714	1.50	5.84	906	43	1.04	70 000
West Asia/N. Africa									
Mediterranean winter rainfall sub-tropics	28 975	10 596	12 503	3.42	5.84	721	24	0.52	18 820
West Asia: Wheat/barley	16 385	2 844	7 188	1.32	3.75	966	24	0.43	42 176
North Africa: Wheat/barley	12 572	7 729	5 315	6.15	16.46	390	83	0.63	10 220
Totals: all regions	293 715	47 963	236 031	1.78	10.40	884	53		

1 *Sources:* Data are based on latest information from a wide range of sources, especially ISNAR country missions, extensive reviews of 12 national research and extension systems in West Africa and Southern Africa by Devres Consultants for AID; replies to questionnaires; reports of CGIAR impact study teams; analyses of national systems; Swanson and Rassi's (University of Illinois) publication on extension resources; and Oram's own collection of reports and other information on national research systems. Additional data on numbers of scientists working on individual crops have been solicited and obtained from CIMMYT, CIP, CIAT, ICRISAT, ILCA, IRRI, and AVRDC especially as a contribution to the ACIAR study. FAO and the World Bank have also been helpful.

2 *Periodicity.* Most data relates to 1980 or later. Financial information, e.g. on national research expenditures, is quoted in terms of constant 1980 U.S. dollars using IMF tables for conversion from local currency to dollars and for adjustment to 1980. Unfortunately there is very little information on extension expenditures and extension data is less complete generally than for research.

3 Based on a normative average of 5 persons per farm family. Number of 'farmers' is therefore obtained by dividing the 1980 agricultural population in Table 3 of the 1981 FAO Production Yearbook by 5.

4 Obtained by dividing national research expenditure by the total number of agricultural research scientists working in the country. Therefore this reflects a scientist module composed of total costs of keeping a scientist in post and not just the salary component.

Table 3.6 Summary Table. Numbers of agricultural scientists identified as working on commodities included in this study in 85 developing countries by geoclimatic region (1984 or latest year).

Geoclimatic regions[1]	Wheat/ barley	Rice	Maize	Sorghum/ millet	Potato	Sweet potato	Ground-nut	Coconut	Banana	Sugar-cane[2]	Pasture/ fodder[3]	All animal scientists[4]
Africa-Sub-Saharan												
– Semi-arid tropics	31	54	65	133	12	33	56	10	0	10	42	520
– Sub-humid tropics	18	16	47	14	4	1	16	0	0	17	21	92
– Equatorial wet tropics	3	32	50	14	3	1	11	4	5	5	21	162
– Humid coastal tropics	1	38	12	9	2	6	0	10	8	37	5	26
– Tropics modified by altitude or latitude	66	32	67	39	23	2	8	24	3	25	44	121
Latin America												
– Subtropical South America	107	26	16	22	25	0	0	4	0	3	28	249
– Tropics modified by altitude or latitude	127	163	73	80	69	27	3	21	18	143	131	888
– Humid tropics, Central America	56	68	102	44	92	5	0	0	9	17	60	427
– Humid tropics, Caribbean	0	71	1	8	24	2	1	7	11	464	63	240
Asia												
– Subtropics/tropics, South Asia	685	982	76	438	365	7	3	15	0	107	95	1 250
– Subtropics, East Asia[5]	0	435	15	9	0	0	0	0	0	150	2	108
– Humid tropics, South/S.E. Asia	0	1 240	200	70	31	163	0	88	0	162	27	652
Oceania												
– Humid tropics (Total Oceania)	0	9	5	0	1	12	0	10	4	14	5	36
West Asia/North Africa												
– Mediterranean winter rainfall subtropics, W. Asia	272	10	27	12	34	0	0	0	0	88	79	397
– Mediterranean winter rainfall subtropics, N. Africa	282	22	13	4	22	0	0	0	0	96	14	591

Source: Compiled by P.A. Oram, IFPRI, from numerous reports of National Agricultural Research Systems, supplemented by information supplied by other International Agricultural Research Centres.

1 These regions are more highly aggregated than the AEZ shown in Table 3.3. It should be noted that some countries fall into more than one region, e.g., India and Brazil have land in the humid and semi-arid tropics and in the subtropics.
2 Includes sugar beet.
3 Included here as indicative of research capacity for ruminant livestock.
4 Pasture and fodder research workers, animal husbandry, nutrition, and veterinary scientists are included in this total.
5 China not included as no scientist-by-commodity breakdown could be obtained. The absence of a country or a notation against a country for a given commodity does not necessarily imply that no research on any of these commodities is in progress, simply that relevant information could not be identified.

Table 3.7. Example of the basic data used for the groundnut application.

Region	General prob. of success	Increment in prob. of success due to ACIAR	Ceiling level of adoption	Unit cost saving (K_{yy}) $US/M.T.	Production ('000 M.T.)	Consumption ('000 M.T.)	World Parity Price $US/M.T.	Exchange rate* (e_t)	Supply elasticity	Demand elasticity
AFRICAWT1	0.48	0.08	0.35	11.10	332	332	221	1	0.30	0.41
AFRICAWT2	0.35	0.05	0.35	11.10	120	178	229	1	0.30	0.41
AFRICAWDT1	0.45	0.05	0.35	11.10	286	309	229	1	0.30	0.41
AFRICAWDT2	0.60	0.10	0.50	11.10	237	218	221	1	0.30	0.41
AFRICAWDT3	0.62	0.12	0.50	11.10	381	357	224	1	0.30	0.41
AFRICASAT1	0.40	0.05	0.30	11.10	233	165	221	1	0.30	0.41
AFRICASAT2	0.80	0.15	0.60	11.10	1567	1364	221	1	0.30	0.41
AFRICASAT3	0.68	0.13	0.45	11.10	987	775	221	1	0.30	0.41
AFRICATM1	0.58	0.08	0.45	11.10	91	91	221	1	0.30	0.41
AFRICATM2	0.60	0.10	0.60	11.10	8	8	221	1	0.30	0.41
AFRICATM3	0.40	0.05	0.40	11.10	27	27	221	1	0.30	0.41
AFRICATM4	0.40	0.05	0.50	11.10	73	66	221	1	0.30	0.41
LATAMWDT3	0.50	0.05	0.45	11.10	65	95	225	1	0.30	0.41
LATAMTM2	0.50	0.10	0.45	11.10	57	58	224	1	0.30	0.41
LATAMTM3	0.63	0.08	0.50	11.10	87	114	228	1	0.30	0.41
LATAMT/ST	0.77	0.12	0.60	11.10	458	418	221	1	0.30	0.41
LATAMSTT	0.65	0.05	0.60	11.10	432	87	221	1	0.30	0.41
ASIAWT1	0.55	0.05	0.60	11.10	19	39	229	1	0.30	0.41
ASIAWT2	0.70	0.15	0.55	11.10	849	855	221	1	0.30	0.41
ASIAWDT2	0.60	0.10	0.55	11.10	222	210	221	1	0.30	0.41
ASIAWDT3	0.55	0.10	0.45	11.10	390	391	221	1	0.30	0.41
ASIASAT2	0.80	0.10	0.60	11.10	5999	5662	221	1	0.30	0.41
ASIAWST	0.75	0.10	0.55	11.10	3494	3327	221	1	0.30	0.41
WANAMED2	0.55	0.05	0.55	11.10	103	99	221	1	0.30	0.41
WANAMED3	0.55	0.05	0.55	11.10	42	31	221	1	0.30	0.41
NAMERICA	0.75	0.0	0.75	11.10	1550	1359	221	1	0.30	0.41
DEVAS	0.70	0.0	0.75	11.10	83	162	229	1	0.30	0.41
DEVOC	0.65	0.0	0.75	11.10	48	71	229	1	0.30	0.41
DEVAFR	0.65	0.0	0.70	11.10	297	174	221	1	0.30	0.41
ODINS	0.0	0.0	0.0	11.10	453	236	221	1	0.30	0.41
ODINC	0.0	0.0	0.0	11.10	0	151	229	1	0.30	0.41
ODEVS	0.0	0.0	0.0	11.10	25	313	229	1	0.30	0.41
ODEVC	0.0	0.0	0.0	11.10	0	1397	229	1	0.30	0.41

* Since prices for each region are measured in $US and slope coefficients calculated using these an exchange rate of 1 is appropriate.

ever, only where marked differences in research capacities could be identified among countries comprising an otherwise homogeneous region, lest the benefits of aggregation not be realised.

On the other hand, when countries seem likely only to be recipients of spillover effects of research conducted elsewhere they can be aggregated. This has required judgments to be made in aggregating countries on whether the resulting regions are likely to be ones with which ACIAR might actively cooperate, or whether they will simply be indirect beneficiaries through research spillovers. An important consideration here is how valuable ACIAR's assistance in fostering cooperation in research between Australia and a developing country (or countries) comprising a homogeneous region might be, both directly and in terms of spillover benefits. Estimates of the likely increment due to prospective ACIAR cooperation were used in this assessment.

3.6 Expected Ceiling Level of Adoption and the Adoption Time Lag (Step 4)

The determinants of adoption of research results is an important and relatively intensively studied area. Two aspects of adoption are important: the chance that successful research results will be used by farmers and the time it is likely to take for the expected ceiling adoption rate to occur. These are discussed separately.

(i) The Ceiling Level of Adoption

As studies such as Herdt and Capule (1983) have discussed, there are a number of factors which influence the chance that the technology options arising out of a successful research program will be adopted by farmers. Apart from the potential financial gains from the technology options these include such things as the education of farmers, quality of extension services, availability of credit, land tenure, communications, market structure, previous exposure to technical change, etc. Information on these factors where available was used in this study to assess the ceiling levels of adoption for each commodity in each country. Some of this information is summarised in Table 3.5. As in the case of probabilities of success, it was necessary in defining homogeneous regions to avoid aggregating countries whose farmers are expected to adopt research results to significantly different ceiling levels even if these countries were 'homogeneous' in most other respects.

Figure 3.2 illustrates the adoption scenarios that were used as the basis for subjective assessments. The smooth curves are the types of adoption

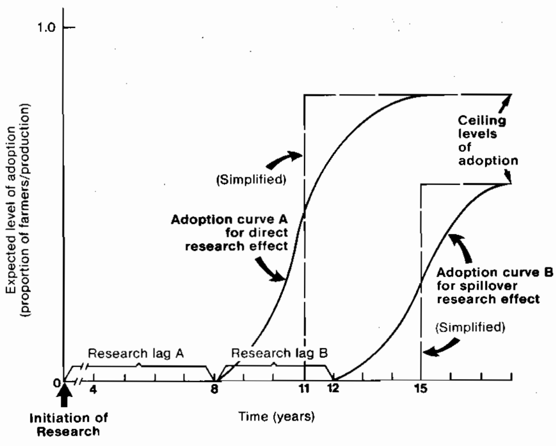

Fig. 3.2. Schematic representation of the ceiling levels of adoption assumed in this study.

relationships hypothesised in most studies. That is, the level of adoption is usually considered to be low as soon as research results become available, with only a few early adopters likely to make use of the research. However, during the following few years the level of adoption increases rapidly until a ceiling level of adoption is reached. Both the rate of increase and the ultimate ceiling level of adoption will depend on the factors discussed above.

In the country where research is undertaken there is the initial research lag *A* before results become available. After this research lag, however, instead of gradual adoption it is assumed that there is an adoption lag and then the ceiling level of adoption is achieved in 1 year. In this case instantaneous adoption is assumed to occur at the mean of the time between the commencement of adoption and the achievement of the ceiling rate of adoption; here this was assumed to be a similar period of 3 years for all commodities.

Two cases are illustrated in Fig. 3.2. Adoption curve *A* and the corresponding simplified stepped adoption line apply to the country where research is undertaken. Adoption curve *B* applies to a country receiving spillover effects from country *A* which require adaptive research before the results can be adopted. In this illustration the ceiling rate of adoption in country *B* is assumed to be lower than in country *A* which is undertaking research. This need not be the case, as apart from the added research lag *B* (see below) adoption rates may be higher or lower for country *B*, depending on the determinants applicable to each country.

An illustration of the subjective ceiling levels of adoption used in this study for groundnuts is given in column 4 of Table 3.7. These are assumed to apply for both direct and spillover research effects.

(ii) Time Lags

Since the discounted present values are the final measures of total benefits, the time lag between the expenditures on research and ultimate adoption is important. For this study it is assumed that research lag *A* associated with completing the initial research is 8 years and the mean lag in adoption of the resultant technology a further 3 years for the simplified stepped relationship assumed here. For countries receiving spillover effects from this research a further research lag *B* of 4 years is assumed to allow for the required adaptive research. The same subsequent mean adoption lag of 3 years was retained. Unlike the expected ceiling levels of adoption which vary considerably between countries and commodities, it was assumed that research lags *A* and *B* and the 3-year adoption lag were the same for all commodities and all countries.

The assumptions on research lags were made after detailed consideration of the available literature (Table 3.8). Although these studies do not provide a conclusive set of lag periods, it was felt that the time periods chosen are consistent with this empirical evidence. These lags have also been confirmed in the recent report of the CGIAR (1985) on the impact of the International Agricultural Research Centres (IARCs) on agricultural productivity.

Table 3.8. Summary of literature on research lags.

Source	Lag *(years)*	Subject under study
Evenson and Jha (1973)	8	The contribution of agricultural research to agricultural production in India.
Kahlon et al. (1977)	5	Productivity of agricultural research in India. Probably also measures extension effects.
Brennan (1986)	17	Australia: semi-dwarf wheats (to first release).
Singh (1977)	8	Aggregate returns to research investment in Punjab, India.
Kumar et al. (1977)	8	Returns on investment in dairy research and extension (flow of benefits commences after 7 years, reaches maximum in 35 years. Research expenditure constant after 13 years.
Evenson (1971)	3–10 av. 6.5	Different regions of the United States. Contribution of agricultural research and extension to production; appears to combine research and adoption lags.
Evenson and Kislev (1975)	5	Average distribution of research spending over 10 years.
Scobie (1979)	10	Investment in international agricultural research. Some economic dimensions.
Dalrymple (1978)	10	North Africa: Wheat. Florence x Aurora; time to first releases.
	7–8	CIMMYT: Mexican wheat. Time to first release.
	4.5	IRRI: IR8 rice. Time to first release.
Billing (1985)	17	Zimbabwe: hybrid corn. Time to first release.
Dalrymple (1986a)	10	Japan: semi-dwarf wheat. Time to first release.
	8–10	Mexico: semi-dwarf Durum wheats. CIMMYT work 1950's to first release 1965.
Dalrymple (1986b)	5	China: early semi-dwarf rice varieties. Time to first release.

3.7 Determine Spillover Effects (Step 5)

For each commodity the steps described so far lead to the grouping of countries into regions which are judged to be relatively homogeneous ecologically for the production of that commodity as well as for the institutional factors which contribute to the success of the research and its adoption by farmers.

The homogeneous regions developed from these assessments are crucial to the determination and incorporation of the spillover effects of research into the analysis. In assessing these spillover effects a two-stage process was used. This process is important because although the estimates eventually used are all subjective, these steps highlight the basic reasoning used in making these judgments. Each step is discussed in some detail.

(i) Determine the Potential Spillover Effect Assuming no Adaptive Research is Required

In this first step of the estimation process the agroclimatic assessments are critical. It is assumed that if factors such as likely levels of adoption and probability of success of adaptive research are ignored, then the comparability of agroclimatic characteristics is the major determinant of how much of the cost-saving impact of research in the originating country will be applicable in any other country. To simplify presentation and analysis, rather than estimate the unit cost-saving, or direct effect of research, in country 'y' and then estimate the proportion of this assessed as the spillover effect, the unit cost saving was defined as unity. The spillover proportion was then assessed in the range zero to unity. To determine the 'k_{fy}', referred to in the formulae in section 2, it is necessary to multiply the matrix of 'spillover effect measures' by the vector of direct unit cost-savings.[10] In this application the latter was assumed to be 5% of the product price.

Using the above method a country with identical agroclimatic characteristics as the country where research is undertaken would have a potential spillover effect value of 1. Countries with similar but not identical agroclimatic characteristics would have potential spillover effects somewhat less than unity. Countries with substantially different agroclimatic characteristics are likely to have potential spillover effects close to zero.

Table 3.9 illustrates the assessment of these agroclimatic spillover effects for the first stage of the estimation for groundnuts. Here the regions listed across the top of the table represent developing countries where research is likely to be funded. In this case all significant groundnut-producing developing countries are included. The regions in the rows of the table are those to which research can feasibly spillover. Since the diagonal elements in the table represent the direct effects of research, these entries are all unity. The rest of the elements range between zero and unity depending upon the evaluation of agroclimatic similarities, based upon the adapted FAO methodology and other commodity or regionally-specific agroecological data referred to in Section 3.4. In the assessments made it was judged that this table is symmetric; that is the spillover from one country to another is the same in the reverse direction. This feature is modified later.

(ii) Determine the Adjusted Potential Spillover When Adaptive Research is Required

On the basis of the empirical evidence referred to in section 3.6 above we have assumed that little research undertaken in one region is directly useable in other countries without further adaptive research effort. If this assumption is correct, the agroclimatic spillover effects in Table 3.9 need to be further modified to take account of differences in the likely success rate of adaptive research among countries. That is, although some countries may be agroclimatically very similar, if there are large differences in the potential of their research systems then the ultimate spillover effect of research could still be different. The spillover effects in Table 3.9 therefore should be adjusted to allow for differences in the probability of success of adaptive research. In this study it was decided that the probability of success for adaptive research was the same as for all research, although application of the framework does not require this.

To adjust the potential agroclimatic spillover indices in Table 3.9 the off-diagonal elements of each column are multiplied by the probability of success of research for the associated region, as described in section 3.5 and Table 3.7. The results of this adjustment for the groundnuts illustration are given in Table 3.10. Notice that the diagonal elements are retained at unity. Also note that the adjusted spillover effects are in some cases reduced significantly and that the table is now not symmetric. The latter reflects the fact that the spillover effect from a country with a strong (adaptive) research system to one with a weak research system will not necessarily be the same as in the reverse direction.[11]

Care is still required in interpreting the information in Table 3.10 as the ultimate spillover effects of research. There are still a number of other factors included in the framework which adjust these potential spillover effects. For example, the probability of success of the original research (direct effect of research) will further discount the potential unit cost reduction due to research in the originating country. Similarly the ceiling level of adoption of final research results will also reduce the impact of spillover effects on output. Again this adjustment occurs through the formulae. The ultimate size of these spillover effects is influenced by additional factors such as price changes, etc. Therefore the eventual spillover impact of research after allowing all interactions to occur will most likely be considerably smaller than may be implied by inspection of Table 3.9, which only considers the relative homogeneity of agroclimates in different countries.

[10]In contrast to the formulae the program in Appendix C uses the agroclimatic spillovers presented in Table 3.9 as the input. Multiplication by the direct effect 'k_{yy}' is undertaken in the program.

[11]The information in Table 3.10 is multiplied by the potential unit cost reduction (Table 3.7) to give the information used in the formulae discussed in section 2. However, note that, as described in footnote 10, the computer program in Appendix C automatically generates the adjusted potential spillover matrix from the original potential agroclimatic spillover matrix and the probability of success vector.

Table 3.9. Potential agroclimatic spillover effects of research if no adaptive research is required: groundnuts.

	Region where research is undertaken																								
	Africa												Latin America					Asia						West Asia/ North Africa	
	WT1	WT2	WDT1	WDT2	WDT3	SAT1	SAT2	SAT3	TM1	TM2	TM3	TM4	WDT3	TM2	TM3	T/ST	STT	WT1	WT2	WDT2	WDT3	SAT2	WST	MED2	MED3
Africa																									
AFRICAWT1	1.0	0.8	0.7	0.4	0.3	0.1	0.1	0.0	0.3	0.2	0.1	0.2	0.3	0.3	0.1	0.6	0.0	0.9	0.8	0.4	0.3	0.1	0.1	0.0	0.0
AFRICAWT2	0.8	1.0	0.9	0.6	0.3	0.1	0.1	0.0	0.4	0.3	0.1	0.3	0.3	0.4	0.1	0.5	0.0	0.7	1.0	0.6	0.3	0.2	0.1	0.0	0.0
AFRICAWDT1	0.7	0.9	1.0	0.8	0.4	0.3	0.3	0.1	0.5	0.4	0.1	0.4	0.4	0.5	0.2	0.4	0.0	0.5	0.8	1.0	0.5	0.3	0.2	0.0	0.0
AFRICAWDT2	0.4	0.6	0.8	1.0	0.9	0.4	0.5	0.2	0.7	0.5	0.3	0.6	0.8	0.6	0.4	0.4	0.1	0.2	0.4	0.9	0.8	0.3	0.3	0.0	0.0
AFRICAWDT3	0.3	0.3	0.4	0.9	1.0	0.9	0.6	0.3	0.7	0.6	0.5	0.4	0.9	0.7	0.4	0.3	0.1	0.1	0.4	1.0	0.8	0.4	0.3	0.0	0.0
AFRICASAT1	0.1	0.1	0.3	0.4	0.9	1.0	0.8	0.6	0.6	0.6	0.5	0.2	0.6	0.5	0.4	0.3	0.1	0.0	0.1	0.7	0.7	0.4	0.4	0.0	0.0
AFRICASAT2	0.1	0.1	0.3	0.5	0.6	0.8	1.0	0.8	0.8	0.7	0.5	0.1	0.7	0.6	0.6	0.3	0.2	0.0	0.1	0.6	0.6	0.9	0.7	0.2	0.2
AFRICASAT3	0.0	0.0	0.1	0.2	0.3	0.6	0.8	1.0	0.4	0.3	0.4	0.0	0.3	0.4	0.4	0.1	0.4	0.0	0.0	0.2	0.3	0.7	0.8	0.4	0.4
AFRICATM1	0.3	0.4	0.5	0.7	0.7	0.6	0.8	0.4	1.0	0.9	0.6	0.4	0.9	0.8	0.6	0.2	0.3	0.0	0.2	0.7	0.8	0.6	0.5	0.2	0.2
AFRICATM2	0.2	0.3	0.4	0.5	0.6	0.6	0.7	0.3	0.9	1.0	0.5	0.3	0.7	0.8	0.5	0.5	0.4	0.0	0.2	0.5	0.7	0.5	0.2	0.1	0.1
AFRICATM3	0.1	0.1	0.1	0.3	0.5	0.5	0.5	0.4	0.6	0.5	1.0	0.4	0.5	0.7	0.8	0.4	0.3	0.0	0.1	0.2	0.3	0.4	0.4	0.0	0.0
AFRICATM4	0.2	0.3	0.4	0.6	0.4	0.2	0.1	0.0	0.4	0.3	0.4	1.0	0.3	0.3	0.1	0.1	0.0	0.0	0.2	0.3	0.3	0.0	0.1	0.0	0.0
Latin America																									
LATAMWDT3	0.3	0.3	0.4	0.8	0.9	0.6	0.7	0.3	0.9	0.7	0.5	0.3	1.0	0.8	0.5	0.6	0.2	0.1	0.3	0.8	0.8	0.7	0.5	0.0	0.0
LATAMTM2	0.3	0.4	0.5	0.6	0.7	0.5	0.6	0.4	0.8	0.8	0.7	0.3	0.8	1.0	0.7	0.5	0.4	0.0	0.4	0.8	0.7	0.6	0.4	0.0	0.0
LATAMTM3	0.1	0.1	0.2	0.4	0.4	0.4	0.6	0.4	0.6	0.5	0.8	0.1	0.5	0.7	1.0	0.4	0.5	0.0	0.2	0.4	0.5	0.5	0.4	0.1	0.0
LATAMT/ST	0.6	0.4	0.4	0.3	0.3	0.3	0.1	0.2	0.5	0.4	0.1	0.6	0.5	0.4	1.0	0.5	0.2	0.3	0.4	0.5	0.4	0.2	0.2	0.0	0.0
LATAMSTT	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.4	0.3	0.4	0.3	0.0	0.2	0.4	0.5	0.5	1.0	0.0	0.0	0.1	0.2	0.3	0.5	0.3	0.3
Asia																									
ASIAWT1	0.9	0.7	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.0	1.0	0.7	0.5	0.3	0.0	0.0	0.0	0.0
ASIAWT2	0.8	1.0	0.8	0.4	0.4	0.1	0.1	0.0	0.2	0.2	0.1	0.2	0.3	0.4	0.2	0.3	0.0	0.7	1.0	0.8	0.5	0.2	0.2	0.0	0.0
ASIAWDT2	0.4	0.6	0.1	0.9	1.0	0.7	0.6	0.2	0.7	0.5	0.2	0.3	0.8	0.8	0.4	0.4	0.1	0.5	0.8	1.0	0.9	0.7	0.5	0.0	0.0
ASIAWDT3	0.3	0.3	0.5	0.8	0.8	0.7	0.6	0.3	0.8	0.7	0.3	0.3	0.8	0.7	0.5	0.5	0.2	0.3	0.5	0.9	1.0	0.8	0.6	0.0	0.0
ASIASAT2	0.1	0.2	0.3	0.3	0.4	0.4	0.9	0.7	0.6	0.5	0.4	0.0	0.7	0.6	0.5	0.4	0.3	0.0	0.2	0.7	0.8	1.0	0.6	0.2	0.1
ASIAWST	0.1	0.1	0.2	0.3	0.3	0.4	0.7	0.8	0.5	0.2	0.4	0.1	0.5	0.4	0.4	0.2	0.5	0.0	0.2	0.5	0.6	0.5	1.0	0.5	0.6
West Asia																									
North Africa																									
WANAMED2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.0	0.0	0.0	0.0	0.2	0.5	1.0	0.8
WANAMED3	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.1	0.6	0.8	1.0
Other																									
NAMERICA	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.1	0.0	0.1	0.0	0.2	0.2	0.2	0.4	0.4	0.5	0.0	0.0	0.1	0.1	0.4	0.5	0.3	0.1
DEVAS	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.5	0.0	0.0	0.0	0.0	0.3	0.6	0.6	0.5
DEVOC	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.2	0.1	0.0	0.0	0.1	0.2	0.2	0.3	0.4	0.2	0.0	0.0	0.2	0.2	0.4	0.4	0.5	0.1
DEVAFR	0.0	0.0	0.0	0.0	0.2	0.0	0.3	0.2	1.0	0.0	0.0	0.1	0.2	0.1	0.2	0.4	0.3	0.0	0.0	0.1	0.1	0.2	0.4	0.4	0.1
ODINS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ODINC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ODEVS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ODEVC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 3.10. Adjusted potential spillover effects of research if adaptive research is required: groundnuts.

	Country/region where research is undertaken																								
	Africa												Latin America					Asia						West Asia/ North Africa	
	WT1	WT2	WDT1	WDT2	WDT3	SAT1	SAT2	SAT3	TM1	TM2	TM3	TM4	WDT3	TM2	TM3	T/ST	STT	WT1	WT2	WDT2	WDT3	SAT2	WST	MED2	MED3
Africa																									
AFRICAWT1	1.0	0.3	0.3	0.2	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.2	0.0	0.4	0.3	0.2	0.1	0.0	0.0	0.0	0.0
AFRICAWT2	0.2	1.0	0.3	0.2	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.2	0.0	0.2	0.3	0.2	0.1	0.1	0.0	0.0	0.0
AFRICAWDT1	0.3	0.4	1.0	0.3	0.2	0.1	0.1	0.0	0.2	0.2	0.0	0.2	0.2	0.2	0.1	0.2	0.0	0.2	0.3	0.4	0.2	0.1	0.1	0.0	0.0
AFRICAWDT2	0.2	0.3	0.4	1.0	0.4	0.2	0.3	0.1	0.4	0.3	0.2	0.3	0.4	0.3	0.2	0.2	0.0	0.1	0.2	0.4	0.4	0.2	0.2	0.0	0.0
AFRICAWDT3	0.1	0.1	0.2	0.4	1.0	0.4	0.3	0.1	0.3	0.3	0.2	0.2	0.4	0.3	0.2	0.1	0.0	0.0	0.2	0.5	0.4	0.2	0.1	0.0	0.0
AFRICASAT1	0.0	0.0	0.1	0.1	0.3	1.0	0.3	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.2	0.2	0.1	0.1	0.0	0.0
AFRICASAT2	0.1	0.1	0.2	0.3	0.4	0.5	1.0	0.5	0.5	0.5	0.3	0.1	0.5	0.4	0.4	0.2	0.1	0.0	0.1	0.4	0.4	0.6	0.5	0.1	0.1
AFRICASAT3	0.0	0.0	0.1	0.1	0.2	0.3	0.4	1.0	0.2	0.2	0.2	0.0	0.2	0.2	0.2	0.1	0.2	0.0	0.0	0.1	0.2	0.4	0.4	0.2	0.2
AFRICATM1	0.2	0.2	0.3	0.4	0.4	0.3	0.4	0.2	1.0	0.4	0.3	0.2	0.4	0.4	0.3	0.1	0.2	0.0	0.1	0.4	0.4	0.3	0.3	0.1	0.1
AFRICATM2	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.2	0.4	1.0	0.3	0.2	0.4	0.4	0.3	0.3	0.2	0.0	0.1	0.3	0.4	0.3	0.1	0.0	0.0
AFRICATM3	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.1	0.2	0.2	1.0	0.1	0.2	0.2	0.3	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0
AFRICATM4	0.1	0.1	0.1	0.2	0.1	0.1	0.0	0.0	0.1	0.1	0.1	1.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Latin America																									
LATAMWDT3	0.1	0.1	0.2	0.4	0.4	0.3	0.3	0.1	0.4	0.3	0.2	0.1	1.0	0.4	0.2	0.3	0.1	0.0	0.1	0.4	0.4	0.3	0.2	0.0	0.0
LATAMTM2	0.1	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.3	0.3	0.3	0.1	0.3	1.0	0.3	0.2	0.2	0.0	0.2	0.3	0.3	0.2	0.2	0.0	0.0
LATAMTM3	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.2	0.3	0.3	0.4	0.1	0.3	0.4	1.0	0.2	0.3	0.0	0.1	0.2	0.3	0.3	0.2	0.1	0.0
LATAMT/ST	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.3	0.3	0.1	0.4	0.3	0.3	1.0	0.3	0.1	0.2	0.3	0.3	0.3	0.1	0.1	0.0
LATAMSTT	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.0	0.1	0.2	0.3	0.3	1.0	0.0	0.0	0.1	0.1	0.2	0.3	0.2	0.2
Asia																									
ASIAWT1	0.4	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	1.0	0.3	0.2	0.1	0.0	0.0	0.0	0.0
ASIAWT2	0.4	0.5	0.4	0.2	0.2	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.0	0.4	1.0	0.4	0.3	0.1	0.1	0.0	0.0
ASIAWDT2	0.2	0.3	0.5	0.4	0.5	0.4	0.3	0.1	0.4	0.3	0.1	0.2	0.4	0.4	0.2	0.2	0.0	0.3	0.4	1.0	0.4	0.4	0.3	0.0	0.0
ASIAWDT3	0.1	0.1	0.2	0.4	0.4	0.3	0.3	0.1	0.4	0.3	0.1	0.1	0.4	0.3	0.2	0.2	0.1	0.1	0.2	0.4	1.0	0.4	0.3	0.0	0.0
ASIASAT2	0.1	0.1	0.2	0.2	0.3	0.3	0.6	0.5	0.4	0.4	0.3	0.0	0.5	0.4	0.4	0.3	0.2	0.0	0.1	0.5	0.6	1.0	0.4	0.1	0.1
ASIAWST	0.1	0.1	0.1	0.2	0.2	0.3	0.5	0.5	0.3	0.1	0.3	0.1	0.3	0.3	0.3	0.1	0.3	0.0	0.1	0.3	0.4	0.4	1.0	0.3	0.4
West Asia North Africa																									
WANAMED2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.2	1.0	0.4
WANAMED3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.3	0.4	1.0
Other																									
NAMERICA	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.1	0.0	0.1	0.0	0.2	0.2	0.2	0.3	0.3	0.4	0.0	0.0	0.1	0.1	0.3	0.4	0.2	0.1
DEVAS	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.4	0.0	0.0	0.0	0.0	0.2	0.4	0.4	0.4
DEVOC	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.2	0.3	0.1	0.0	0.0	0.1	0.1	0.3	0.3	0.3	0.1
DEVAFR	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.6	0.0	0.0	0.1	0.1	0.1	0.1	0.3	0.2	0.0	0.0	0.1	0.1	0.1	0.3	0.3	0.1
ODINS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ODINC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ODEVS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ODEVC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

3.8 Derive Prices, Transportation Costs, and Elasticities (Step 6)

Prices

(i) Tradeable Commodities: In its study of 'Price Prospects for Major Primary Commodities' the World Bank (1984) has projected prices (in 1983 US dollars), for eight of the twelve agricultural commodities included in this report. These prices are based on those prevalent in the largest producing and exporting countries which play a major role as price setters for the respective commodities. Since the effects of research initiated in the immediate future will in most cases not be felt before 1995 it was decided that these projected rather than current prices be used wherever feasible.

For sheep and goat meat, which was not included in the World Bank projections, 1979–81 average prices expressed in 1983 dollars were used since the projections for a comparable product, beef, show no significant change by 1995. The world prices used are listed in Table 3.11.

For some commodities there are no international prices available because the primary product is not a major tradeable commodity. This applies for example to fresh coconuts and to groundnuts-in-shell. Here we used the main tradeable product extracted from that commodity (copra in the case of coconuts and oil in the case of groundnuts) and expressed the output in terms of processed commodity equivalents. A weighted average was used when the conversion factors differed between major exporting countries.

(ii) Non-tradeable Commodities: For non-tradeable commodities (i.e. potato, sweet potato and pulses) there is no 'world' price and domestic prices had to be used. In this study the FAO 'Statistics on Prices received by Farmers 1982' was the main source for determining 'farmgate' prices. As the data are in local currencies they were converted to US dollars for the appropriate year, using the International Monetary Fund's publication of International Finance Statistics (IFS) for exchange rate calculations and then adjusted to 1983 dollars using the United States CPI. Where necessary regional price was calculated by weighting the price in each country of a region by its production.

Applying a standard 5% cost reduction (k_{yy}) in cases where there are regional variations in calculated non-tradeable prices results in differential dollar reductions. This does not occur with the tradeable commodities.

Care needs to be exercised in using 'farmgate' prices because these prices may include local subsidies or taxes, which would bias the benefits accruing to research. Information on subsidy and tax components of national prices of non-traded crops is limited, but consideration of available evidence indicates that non-tradeables, which include most roots and tubers, pulses, tropical fruits, and vegetables, are not usually subsidised or taxed. In this context, it is germane to quote the response of the International Potato Centre to the TAC (1985) Priorities Paper's use of 'world' prices for potatoes as a means of valuing production of that commodity in the determination of research priorities. This response states: 'In the case of many crops which are not freely traded these (prices derived from world trade figures) have no

Table 3.11. Prices and transport costs used in computing benefits (1983 $US/t).

Commodity	Prices	Transport Costs[1]	Unit
Banana	275	17–49	Central and South America, fob US ports (plantain prices not available).
Coconut	80	4–14	Nuts: derived from average bulk copra prices in Philippines/Indonesia.
Groundnut	221	3–8	Nuts in shells, derived from oil prices.
Maize	113	10–49	US No.2 yellow fob Gulf ports.
Rice	327	9–24	Thai 5% broken, fob Bangkok.
Sheep and goat meat	2204	143–340	Frozen whole carcass, Smithfield Market, London.
Sorghum	108	11–19	US No.2 yellow, fob Gulf ports.
Sugar	315	15–27	World ISA daily price, fob main Caribbean ports.
Wheat	130	14–30	Weighted average US No.1 soft red winter, Gulf and Canadian No.1 Western Red Spring, Thunder Bay.
Potato[2]	115–305	not traded	Average farm gate prices, 1979-81, FAO.
Pulses[2]	194–1077	not traded	Average farm gate prices 1979–81 FAO.
Sweet Potato[2]	44–546	not traded	Average farm gate prices, 1979–81 FAO.

Source: World Bank (1984), FAO (1982)

[1] Excluding inland freight.

[2] No world price was available for these commodities as they are not internationally traded. Prices are average farmgate prices in each country.

value. We insist that proper farmgate prices, as published by FAO, are in most cases the only useful values for this analysis.'

We have essentially reached a somewhat similar conclusion, partly from necessity in the absence of any apparent viable alternative; partly because we feel that fears of serious *price* distortions due to subsidies may be groundless for the major non-tradeables—roots, tubers, pulses and vegetables.[12]

Transportation Costs

Transportation costs can be calculated in a number of ways. For some commodities (i.e. wheat, frozen beef, lamb) the transportation costs from some exporting countries to some importing countries can be obtained directly from the literature. Wherever available, insurance, local transit charges, etc., were included in transportation costs. In this study a 'transportation cost matrix' obtained from published data was applied to the 1983 price for wheat (USDA 1980). This shows the transportation costs of wheat between various points of origin and destination throughout the world. This matrix was adapted for use on rice, maize, and sorghum. Ideally, a trade table should be constructed in parallel to show the origin and destination of each traded commodity. The quantity from each exporter can then be converted to a percentage of each importer's total import quantity. This, however, only proved possible for a few commodities.

Where adequate data were available the transportation cost matrices and the trade tables were used to determine an average shipping cost for each country or each homogeneous region. When this method of calculating transportation costs could not be used because of lack of data, approximate figures from different origins to different destinations were estimated using c.i.f./f.o.b. ratios obtained from the IFS tables. A 'rule of thumb' suggested by the World Bank (1983–84) is to assume between 10 and 15% of the f.o.b. value as a transportation cost. For each commodity the appropriate total transportation cost must be added to or subtracted from the 'world price' to obtain regional import or export parity prices.

When there were several countries in a single 'homogeneous' region (for purposes of empirical analysis), some of which were importers and others not, a weighted average transport cost using country consumption figures was used. Thus a single parity price was determined for each region for each commodity. Due to lack of data, none of these estimates takes account of internal transport costs in importing countries. Hence the benefits of research may be overvalued in some cases—especially for large landlocked countries with high transport costs from the nearest port.

Elasticities

The first step in determining elasticities was a literature search related to each commodity. In some cases it was possible to find the estimates of direct elasticities for some commodities and countries from FAO or World Bank data and UNCTAD (1974). A problem with the use of such estimates is that the methods employed often vary and are not always clearly specified (e.g. between short, medium and long-term elasticities). Given the time lags involved in research longer-term estimates have been used where available.

If no elasticity estimates were available for a particular commodity, indirect methods were adopted. For some commodities, for example edible fats and oils, end-uses can substitute for one another. When the elasticities of one such commodity for one or more regions could not be obtained directly, they were derived from a substitute commodity.

For commodities and/or countries where no estimates exist of demand elasticities an approximation was used, as in the following example for potato.

First the percentage of calories which each country obtains from potatoes was calculated. A high percentage of calorie consumption indicates that consumers are likely to be very sensitive to a small decrease in the quantity supplied, and therefore such a decrease could have a large effect on prices. Thus for countries where consumers derive a high percentage of calories from potatoes the price elasticity of demand is estimated to be small (absolutely), and where their dependence on this crop is low, the price elasticity will be large. The proportion of calories which is derived from potatoes is highest in Bolivia. Therefore, we assumed a low absolute price elasticity of demand for Bolivia of 0.2 and used this as the basis for calculating the price elasticity of demand for the other countries and regions. For developed countries the average demand elasticity of the United States was used as the figure for North America, Western Europe and Oceania.

The weighted average of the supply elasticities of the countries in North America, Europe and Oceania was used for other developed market economy countries, for Centrally Planned Europe, and for Centrally Planned Asia (excluding China). The weighted average supply elasticity of Syria,

[12]Of course distortions to quantities produced of the main *tradeables* due to domestic subsidies and taxes remain a potential shortcoming of this analysis, even though the availability of a 'world price' enables an appropriate valuation of increments to output resulting from research.

Table 3.12. Summary of price elasticity estimates used in this study

	Developing countries				Developed countries				
Commodity	Sub-Saharan Africa	Latin America	Asia	W Asia/ N Africa	North America	West Europe	East Europe	Japan	Oceania
				Price elasticity of demand					
Maize[1,8,5]	.10	.10-.30	.20-.30	.20	.50	.50	.30	.50	.50
Sorghum[1,8,5]	.20-.30	.20-.50	.20-.50	.30	.40	.70	.20	.10	.40
Rice[1,8,5]	.35-.40	.30-.40	.10-.30	.50	.25	.30	.30	.25	.30
Wheat[1,8,5]	.40-.45	.20-.40	.50	.20	.20	.30	.20	.33	.10
Sugar (Cane)[4]	.19-.33	.19-.33	.26-.42	.33	.17	.17	.19	.17	.17
Coconut[1,5]	.90	.90	.80-.90	.80-.90	.31	.31	.49	.8-.9	.49
Groundnut[5,8]	.41	.41	.41	.41	.41	.41	.41	.41	.41
Banana/Plantain*	.40	.40	.40	.40	.40	.40	.40	.40	.40
Potato*	.36-.39	.28-.38	.37-.40	.39	.35	.22	.32	.38	.32
Sweet Potato*	.76-.80	.75-.80	.63-.80	.80	.80	.80	.80	.80	.80
Pulses*[2]	.40-.76	.65-.79	.76-.78	.74-.75	.79	.78	.78	.50	.80
Sheep/Goat Meat[1,5,6,8,7]	1.00	.42-.56	1.61-1.76	.96-1.36	.65	.68	.68	.86	.54
				Price elasticity of supply					
Maize[1,8,5]	.10	.10-.30	.10	.10-.20	.40	.40	.30	.40	.40
Sorghum[1,8,5]	.10	.30	.10-.30	.10	.30	.30	.20	.20	.30
Rice[1,8,5]	.13-.18	.30-.40	.20-.30	.25	.20	.30	.30	.40	.30
Wheat[1,8,5]	.10	.20-.30	.20	.30	.20-.40	.30	.20	.40	.40
Sugar (Cane)[4]	.45	.44-.65	.25-.32	.32	.23	—	—	.43	.37
Coconut[1,5]	.66	.66	.66	.66	.55	.66	.66	.66	.30-.66
Groundnut[5,8]	.30	.30	.30	.30	.30	.30	.30	.30	.30
Banana/Plantain*	.40	.40	.40	.40	.40	.40	.40	.40	.40
Potato*	.40	.40	.49	.38-.50	.51	.32	.64	.64	1.09
Sweet Potato*	.50	.50	.50-.70	.50	.50	.50	.50	.50	.50
Pulses*[2]	.40	.40	.51	.15-.54	1.70	.53	2.50	.79	2.50
Sheep/Goat Meat[1,5,6,8,7]	1.76	1.07	1.76	1.76	.68	.30	.30	.40	.70

* See note in text on proxy procedure for calculating Es and Ed.
Sources: [1] UNCTAD (1974); [2] Askari and Cummings (1976); [3] Valdes and Zietz (1980); [4] De Vries (1980); [5] World Bank (unpublished sources); [6] FAO (unpublished sources); [7] Fine and Lattimore (1982); [8] USDA (1978).

Jordan and Lebanon was used as a basis for other Asian countries (Askari and Cummings 1976). For non-Asian developing countries we have adopted the domestic supply elasticity figure of 0.4 cited by Valdes and Zietz (1980).

Table 3.12 provides a condensed outline of the supply and demand elasticities used in the analysis for the 12 commodities considered in this report. In this table the major geographical areas for developed and developing countries are used and ranges of elasticities for countries within these areas presented.

4. Results of the Empirical Analysis

4.1 Introduction

To date assessments have been completed for 12 commodities using the computer routine developed to make the model operational (Appendix C). Eventually it is planned to cover all 24 commodities listed in Table 3.1.[13] A 30-year planning horizon has been assumed, a 5% unit cost reduction, an 11-year research and adoption lag for direct effects of research and a 15-year combined lag for spillover effects. For each commodity the total economic benefits, net spillover benefits and distributive implications for each region have been estimated. Even for the initial 12 commodities with on average about 30 homogeneous regions each, the detailed results are extensive. For an indication of the complete information generated, an example for groundnuts is included in Appendix D. As a starting point for priority discussions this full set of information for all commodities is too detailed. It is, however, possible to produce a summary table which still contains most of the important points. Table 4.1 illustrates, again for groundnuts, the type of information that can be included in this summary form.

In brief the table shows that groundnut research which is focused on the Asian semi-arid tropics (SAT) and warm subtropics (WST) would generate the greatest expected international benefits of around $US105 million and $US75 million respectively. Not far behind these regions is semi-arid tropical region 2 of Africa with expected international benefits of $US69 million. However, in Africa the bulk of the benefits ($US49 million or about 70%) would accrue to countries outside the African SAT in the form of spillover effects. For research in the Asian SAT on the other hand, only about 30% of the benefits ($US29 million) would accrue to countries outside that region. The benefits from ACIAR programs in groundnuts are judged to be greatest if they are focused on the semi-arid tropical regions of Asia (i.e. India) or in the SAT2 region of Africa (i.e. in Burkina-Fasso, Mali, Mozambique, Nigeria or Senegal).

In general, consumers would receive about 40% of the benefits from groundnut research and producers 60%. Most of the consumers and producers who benefit would be from developing countries.

For this report, however, which is regarded as a first step in introducing this framework to priority discussions, even the volume of information contained in the set of 12 tables similar to Table 4.1 is considered excessive. A more concise summary of this information is best used to provide an overall indication of the implications of research on different commodities in different countries. Once this overall view is available the specific objectives of an institution can be used to focus attention on which aspects of the complete information are then worth presenting or discussing in more detail. The aim of this report, therefore, is to provide only an initial overall perspective.

4.2 Aggregate International Benefits from Research

4.2.1 International Benefits

To summarise the results contained in the commodity tables like Table 4.1, aggregate averages were used. For the 12 commodities analysed so far these averages were calculated for all developing countries as a group and also for the five main geographical regions separately. The results for total international benefits are given in Table 4.2. In this table the commodities are listed in the order of the highest gross benefits to the lowest for the average of all developing country regions.

Overall, rice is expected to provide considerably greater average international benefits from research than any of the other commodities

[13]To undertake the empirical analysis for this study a substantial amount of data is being assembled. Until it has been collated for the 24 commodities it has not been possible to review all the data to ensure its consistency. The results for these first 12 commodities should therefore be regarded as preliminary and as providing indicative rather than definitive measures of the potential impacts of alternative international research portfolios.

Table 4.1. Groundnuts — Summary of present value (PV) and distribution of the benefits from research resulting in a 5% unit cost reduction

Region where research is undertaken	Total International Benefits ($mUS)	Spillover Benefits ($mUS)	Benefits due to ACIAR Increment ($mUS)	Distributive effects (% of total benefits[1])							Cost of Research[2]
				Consumers			Producers				
							Developing				
				Developing	Developed	Total	Gainers	Losers	Developed	Total	
Africa											
Warm wet tropics	8	7	1	39	7	46	63	-4	-3	56	H
Warm humid tropics	7	7	1	34	7	42	67	-5	-3	59	H
Warm dry tropics 1	13	12	1	34	7	41	66	-3	-3	60	H
Warm dry tropics 2	21	19	3	33	7	40	65	-2	-3	60	M
Warm dry tropics 3	28	25	5	33	7	40	58	-2	-3	59	H
Semi-arid tropics 1	17	16	2	34	8	42	66	-3	-3	60	M
Semi-arid tropics 2	69	49	13	32	7	39	67	-4	0	63	H
Semi-arid tropics 3	47	39	9	33	7	40	66	-5	0	61	H
Tropical modified 1	32	31	4	34	8	42	61	-2	0	59	H
Tropical modified 2	24	24	4	34	8	42	61	-1	0	60	H
Tropical modified 3	14	14	2	34	8	42	65	-3	-3	59	L
Tropical modified 4	5	4	1	33	7	40	56	-17	20	59	H
Americas											
Semi-arid tropics	29	29	3	34	8	42	59	-2	1	58	M
Tropical modified 1	26	26	5	34	8	42	58	-2	2	58	M
Tropical modified 2	31	30	4	34	8	42	53	-2	8	59	H
Tropics/subtropics	33	28	5	33	7	40	52	-3	11	60	H
Transitional	28	24	2	32	7	39	52	-5	14	61	H
Asia											
Warm wet tropics	3	3	0	37	7	44	89	-29	-3	57	H
Warm humid tropics	22	13	5	30	6	36	71	-4	-3	64	L
Warm dry tropics 1	36	34	6	34	8	42	63	-3	-1	59	L
Warm dry tropics 2	36	34	7	34	7	41	63	-2	-1	60	L
Semi-arid tropics	105	29	13	30	5	35	66	-3	2	65	L
Warm subtropics	75	36	10	31	6	37	61	-3	5	63	M
West Asia/North Africa											
Mediterranean 1	16	15	1	33	8	41	53	-8	15	60	M
Mediterranean 2	13	12	1	34	8	42	63	-9	4	58	L

[1] Due to rounding errors consumer and producer shares sometimes do not add to 100.

[2] Based on weighted averages for each region. H: High, average costs $50 000 + per scientist. M: Medium, average cost $25–49 000 per scientist. L: Low, average cost under $25 000 per scientist (based on 1980 costs).

Table 4.2. The expected present value of average international benefits from research: all developing countries and main regions[1] ($US M 1983).

Commodity	All developing countries	Africa	West Asia/ North Africa	Americas	Asia	South Pacific
Rice	658	337	401	447	1166	—
Potato	285	71	429	241	393	—
Wheat	279	57	540	283	330	—
Sugar	139	74	134	159	186	—
Maize	138	60	149	173	248	—
Sweet potato	136	68	39	142	213	—
Bananas/plantains	126	102	24	140	150	122
Pulses	124	62	102	137	213	—
Sheep and goats	68	36	91	102	99	—
Coconut	53	32	—	49	97	43
Sorghum	52	36	26	56	103	—
Groundnuts	30	24	15	29	46	—

[1] An initial unit-cost reduction of 5% from research is subsequently adjusted by the differential probabilities of success, spillover effects and adoption potentials for the various regions and commodities using the formulae, to derive benefit estimates.

considered. Although the average international benefits to potato and wheat are high, they are considerably lower than for rice. In absolute and to a lesser extent relative terms, the difference is less substantial for the other crops, with groundnuts providing the lowest average international benefits of the commodities considered so far. There is not much to choose among sugar, maize, sweet potato, bananas/plantains, and pulses in terms of overall research benefits. Nor is there among sheep and goats, coconut and sorghum.

An alternative way of presenting the differences in total international benefits between commodities and between regions is to ask the question: how much larger than 5% would the unit cost reduction need to be in alternative commodities and/or countries to achieve the same level of benefits as those indicated for rice research? Table 4.3 provides this type of information. Choosing the base for comparison becomes important. For this illustration the base used was the all-country average international benefits for rice. In Table 4.3 this has an index of 1 and therefore all other entries are the multiples of 5% unit cost reductions required to achieve the same relative level of international benefits as a 5% unit cost reduction for rice. Thus, at the most aggregative level, for potato or wheat research to be expected to achieve

Table 4.3. Unit cost reduction required to achieve equivalent total international benefit to the all-country average for rice[1].

Commodity	All developing countries	Africa	West Asia/ North Africa	Americas	Asia	South Pacific
Rice	1.0	2.0	1.6	1.5	0.6	—
Potato	2.3	9.3	1.5	2.7	1.7	—
Wheat	2.4	11.5	1.2	2.3	2.0	—
Sugar	4.7	8.9	4.9	4.1	3.5	—
Maize	4.8	11.0	4.4	3.8	2.7	—
Sweet potato	4.8	9.7	16.8	4.6	3.1	—
Bananas/plantains	5.2	6.5	27.4	4.7	4.4	5.4
Pulses	5.3	10.6	6.5	4.8	3.1	—
Sheep and goats	9.7	18.3	7.2	6.6	6.6	—
Coconut	12.4	20.6	—	13.4	6.8	15.3
Sorghum	12.7	18.3	25.3	11.8	6.4	—
Groundnuts	21.9	27.4	43.9	22.7	14.3	—

[1] The unit-cost reduction for rice in All Developing Countries is set to an index value of 1 and the other figures represent the break-even multiples.

the same total benefits as rice research, more than twice the unit cost saving would have to be generated from the equivalent research effort. Alternatively for groundnuts 22 times the unit cost reduction for rice would have to be achieved.

The importance of the research cost assumption is highlighted by these figures. As pointed out in section 2, for the analysis here it is assumed that a 5% unit cost reduction is expected to be achieved with approximately the same level of research expenditure for all commodities in all countries/regions. At the aggregate level it is not possible to determine the precise cost differences required. As was pointed out earlier some account is taken of these differences through factors such as the probability of success, spillover parameters and levels of adoption. The more disaggregated the discussion of priorities becomes the easier it is to more accurately specify these cost differences.

Returning to the present value of international benefits, at a less aggregated level the 'all country' pattern of relative international benefits is retained for the Asian, South Pacific and Americas regions in the case of most commodities. However, in Africa and West Asia/North Africa the relative benefits of research on these commodities is changed. In the latter wheat has the highest expected benefits, being now significantly more than rice. In the former bananas/plantains moves from sixth place to second behind rice with wheat and maize being displaced by sweet potato and pulses.

From a regional point of view research in Asia has higher benefits in value terms than the other regions for all commodities, except wheat and sheep and goats.

4.2.2 Spillover Benefits

Since national research administrators may base research priority assessments only on the national benefits arising from research, it is likely that international institutions may as part of their research funding objectives place emphasis on the spillover benefits from research. Table 4.4 shows the expected present value of average spillover benefits in the same format as in Table 4.2. These spillover benefits are the share of the international benefits which are received by regions other than the region where the research is in fact undertaken. Two points emerge from this table.

First, the pattern of relative benefits is similar to that for the total international benefits of Table 4.2, both with respect to different commodities and between geographical regions. Second, as seen from column 3 of Table 4.4, on average spillover benefits represent a high proportion of the aggregate international benefits, ranging from 65% for rice to 82% for potatoes. If, as expected, national governments do not take these spillover effects into account in determining the expected benefits to research undertaken in their country, then their investment decisions may be based on considerable underestimation of total benefits. From an international perspective failure to take account of these externalities could well lead to underinvestment and/or a less efficient pattern of investment by individual national research systems.

4.2.3 Benefits to ACIAR Incremental Involvement

Table 4.5 provides the same type of information but for the expected increment to international

Table 4.4. The expected present value of average spillover benefits from research: all developing countries and main regions[1] ($US M 1983).

Commodity	All Developing Countries: Average	All Developing Countries: Proportion of total benefits	Africa	W Asia/ N Africa	Americas	Asia	South Pacific
Rice	428	.65	328	352	421	519	—
Potato	235	.82	69	397	221	272	—
Wheat	222	.80	56	450	265	196	—
Sugar	95	.68	68	108	105	107	—
Maize	104	.75	55	133	135	157	—
Sweet potato	104	.77	66	38	139	112	—
Bananas/plantains	95	.75	83	22	96	116	114
Pulses	98	.79	58	81	124	125	—
Sheep and goats	54	.79	32	64	94	63	—
Coconuts	38	.72	30	—	46	36	41
Sorghum	40	.77	31	25	45	63	—
Groundnuts	22	.73	21	14	27	25	—

[1] An initial unit-cost reduction of 5% from research is subsequently adjusted by the differential probabilities of success, spillover effects and adoption potentials for the various regions and commodities using the formulae, to derive benefit estimates.

Table 4.5. Expected present value of the increment to research benefits due to ACIAR involvement: developing countries and main regions[1] ($US M 1983).

Commodity	All developing countries	Africa	West Asia/ N.Africa	Americas	Asia	South Pacific
Rice	75	42	31	67	113	—
Potato	47	13	69	41	64	—
Wheat	43	10	98	45	41	—
Sugar	18	13	15	21	20	—
Maize	19	9	20	25	33	—
Sweet potato	17	11	3	14	30	—
Bananas/plantains	18	15	2	19	19	30
Pulses	22	12	21	21	43	—
Sheep and goats	13	6	19	17	21	—
Coconut	9	5	—	8	17	7
Sorghum	7	6	3	6	15	—
Groundnuts	4	4	1	4	7	—

[1] An initial unit-cost reduction of 5% from research is subsequently adjusted by the differential probabilities of success, spillover effects and adoption potentials for the various regions and commodities using the formulae, to derive benefit estimates.

benefits due to ACIAR's partnership involvement in research in developing countries. As discussed earlier, this increment is calculated as an increased probability of success in the funded research due to Australian scientific involvement. If ACIAR's sole objective were to choose commodities and regions which maximise these incremental benefits, Table 4.5 shows that similar priorities would apply as for the total benefit measures discussed above. That is, rice still dominates as the commodity with the largest expected benefits and the Asian region is the dominant region for virtually all crops. The exception is wheat and potato, which are the dominant commodities for the West Asia/North Africa region.

4.2.4 Summary and Comparison with Other Studies

In summary, the initial priority assessment that emerges from the aggregated average benefit estimates for the 12 commodities summarised in Tables 4.2 to 4.5 leads to the following conclusion: irrespective of which objective ACIAR considers to be most important, that is, maximising international benefits, spillover benefits or incremental benefits, approximately the same priority ordering of commodities and regions would apply. In general this conclusion implies that on average it is possible to identify countries in Asia where funding of collaborative rice research will have higher total benefits than either rice research in other non-Asian developing countries or other commodity research in Asia or other parts of the developing world. In discussing priorities this information is quite aggregative and more detailed information is required to highlight important differences between individual countries.[14]

The literature does not include very many studies of the ex ante type attempted here. It is therefore not possible to compare the results obtained relative to others. Much of the research evaluation literature, both ex post and ex ante, has concentrated on national research benefits. As suggested earlier these have been summarised often; for example see Ruttan (1982). Most have used rates of return measures to assess benefits. Because of the cost assumptions and the importance given to the distribution of benefits this has not been the form of presentation adopted in this study. Despite this the national benefit estimates here are probably similar to many of those in the studies reported by Ruttan (1982). This study does, however, emphasise the importance of the spillover benefits and the fact that these are substantial relative to national benefits in most if not all situations. If this is correct then the rates of return estimated in previous studies are likely to be significantly underestimated if total international benefits are considered.

A recent review of the impact of interntional agricultural research centres (CGIAR 1985) suggested that the total benefits from past research on rice and wheat was substantial: 'the new varieties typically outyield the old varieties by 400 to 500 kilograms per hectare. Thus worldwide, they

[14]Copies of the disaggregated tables are available from the authors but will become available in a more detailed, expanded report on this study which will cover 24 commodities.

annually provide over 50 million tons of additional food' (CGIAR 1985, p.6). The current value of the increased production attributable to the modern varieties alone is extremely high at close to $US10 billion annually (CGIAR 1985, p.5) and with a current annual cost of about $US180 million results in a substantial rate of return. Most of these benefits are via spillover effects as has been quantified for some recipient countries by Brennan (1986) and Dalrymple (1980).

Apart from this assessment some other studies have attempted to quantify the magnitude of the total economic value of spillover effects of research. Evenson et al. (1979) considered spillover effects within US agriculture. Table 4.6 summarises their results. It indicates that for the US, postwar spillover effects between states ranged from 0 for extension effort to 68% of benefits for science-oriented research. Although these estimates do not take account of spillover benefits to other countries they are not too dissimilar to those found in the present study.

Another study by Evenson (1977) provides evidence of the substantial spillover effects that can be expected internationally from agricultural research (Table 4.7). The order of these spillover benefits for developing countries is in the same range if not slightly higher than those indicated in Table 4.4.

4.3 Distribution of Research Benefits

The previous section discussed the total benefits from research. Objectives that are important to institutions which fund international agricultural research often include dimensions which place considerable emphasis on the distribution of research benefits between different countries and groups within countries. This section summarises the type of information generated by this analysis which attempts to quantify some of these distributional implications.

Before highlighting results for the individual commodities it is useful to identify some of the factors which cause the substantial variation in the distribution of the research benefits for the 12 commodities. The share of total benefits accruing to developed or developing country consumers is determined largely by their share of total consumption. To a lesser extent the relative elasticities of demand between these two categories of countries will also affect this share. The proportion of total producer benefits received by developed or developing country producers is also influenced by their relative contribution to production and to a lesser extent by their relative elasticities of supply.

The main factors influencing the share of developing country producer benefits that are in the form of gains or losses are, first, the extent of spillover effects and, second, the production share of countries that receive no spillover effects. These losses are due to the lack of cost-saving from research for producers in some countries but a decrease in the world price due to increased output in countries where research is applicable. Finally, the share of total benefits received by consumers and producers in aggregate is largely influenced by the relative elasticities of supply and demand at the aggregate level.

Sensitivity analysis with respect to all these factors for all countries is a time-consuming task and has not been attempted at this point in this study. Such analyses are probably best left to situations when the framework is applied at the individual country or project level rather than at the aggregate level considered here.

If the distribution of benefits for each commodity is considered the complexities of decision-making aimed at achieving distributive objectives are soon apparent. With an objective of maximising total international or spillover benefits it became clear in the previous section that rice research in Asia had the highest payoff. If the distributive objective is to undertake research which provides benefits mostly to producers and consumers in developing countries, but in addition does not disadvantage members of either of these broad groups, then rice may not satisfy this

Table 4.6. Estimated impacts of research and extension investments in U.S. Agriculture.

Period and subject	Annual rate of return (%)	% of productivity change realised in state undertaking the research
1868–1926:		
All agricultural research	65	not estimated
1927–50:		
Technology-oriented agricultural research	95	55
Science-oriented agricultural research	110	33
1948–71:		
Technology-oriented agricultural research		
South	130	67
North	93	43
West	95	67
Science-oriented agricultural research	45	32
Farm management and agricultural extension	110	100

Source: Evenson et al. (1979).

Table 4.7. Estimated marginal benefit streams associated with national research investment of $1 000.

Benefit streams	Research investment			
	Developed countries		Developing countries	
	Technology-oriented	Science-oriented	Technology-oriented	Science-oriented
Part 1				
Appropriated by investing country				
(a) Direct contribution	630	12 300	3 710	35 600
(b) Through complementarity with research in other countries	1 620	1 620	7 200	7 200
Total appropriatable benefits	2 250	13 920	10 910	42 800
Part 2				
Contributed to other countries	5 150	17 000	49 000	37 300
Total international benefit stream (Part 1 + Part 2)	7 400	30 920	59 910	80 100
Part 3				
Realised by a typical country from research investment by other countries in similar climate zones (or regions)				
(a) With average indigenous research	8 580	550	55 000	1,700
(b) With no indigenous research capability	4 560	520	1 700	1 700

Source: Evenson (1977, p.250).

objective well (Table 4.8). Clearly, developing country consumers receive a substantial share (45%) of the benefits from rice research. In addition, the bulk of the remaining benefits accrue to developing country producers. However, some of the latter group also experience substantial aggregate losses as a result of rice research undertaken in other countries.

If in addition to the above objective it is also considered desirable not to cause large losses to producers in developed countries then the commodities which seem to best satisfy this objective are bananas/plantains, sweet potato, coconuts and groundnuts. All four commodities have virtually

Table 4.8. Distribution of research benefits: average for all developing countries.

Commodity	Share of benefits received by each group (%)						
				Producers			
	Consumers			Developing			
	Developing	Developed	Total	Gainers	Losers	Developed	Total
Rice	45	3	48	69	-18	1	52
Potato	16	41	58	52	-3	-5	42
Wheat	22	24	46	48	-5	11	54
Sugar	31	27	58	61	-12	-7	42
Maize	16	25	41	56	-7	10	59
Sweet potato	47	—	47	55	-2	—	53
Bananas/plantains	40	5	45	58	-3	—	55
Pulses	27	9	36	71	-4	-1	64
Sheep and goats	45	31	76	51	-8	-18	24
Coconut	37	6	43	58	-1	—	57
Sorghum	24	12	35	65	-3	3	65
Groundnuts	33	7	41	63	-5	2	59

all benefits accruing to developing country consumers and producers. In addition only small losses are imposed on developed country producers and relatively small losses result for some developing country producers.

If distributive objectives are of considerable importance in decision-making and if it is clear that producers and consumers of these four commodities are approximately the same groups of people, then by using the tables it is possible to reassess commodity and regional priorities.

Converting the percentages into value terms accruing to each group gives a similar result to those illustrated earlier. That is, banana/plantain and sweet potato research are likely to result in about the same level of total benefits; however, this is more than four times the benefits expected from groundnuts and twice that from coconuts. Therefore unless the unit cost savings from similar research expenditures on each commodity are expected to be substantially different at the aggregate average level, bananas/plantains and sweet potato research should rate a higher priority than coconuts or groundnuts and in addition, on benefit distribution grounds, may take priority over the other commodities, including rice.

However, in making the above assessment it is important to keep in mind the likely magnitude of the benefits foregone in giving significant weight to the likely distributive effects of research. Using the average figures from Table 4.2, the foregone benefits (or opportunity costs) of funding sweet potato or banana/plantain research rather than rice are more than five times the benefits that are likely to result from sweet potato or banana/plantain research.

The above discussion relies on aggregative information and therefore represents only a preliminary indication of the important factors. More detailed and extensive implications of the distributive impact of research can be found by closer consideration of the complete information produced using the framework developed here. Appendix D illustrates this for groundnuts.

5. Conclusions

The aim of this paper was to develop a framework which can be used in the assessment of commodity and regional agricultural research priorities from an international perspective. As the empirical analysis demonstrates, the methodology illuminates not only the relative economic benefits from alternative strategies but also the trade-offs which might be implied in the distribution of benefits between consumers and producers in different regions. These considerations are usually germane to policymakers who are required to make judgments about the allocation of scarce research resources.

In the analysis completed so far the substantial returns to further investments in rice research are clearly indicated. It is estimated that rice research could generate more than twice the benefits of research on potato and wheat, the second and third ranked commodities. On the other hand, bananas/ plantains, sweet potato, coconuts and groundnuts offer developing country producers and consumers a larger share of the economic benefits of research than any of the other commodities examined. This more equitable result could come however at a substantial opportunity cost in terms of foregone total economic benefits from research on rice and several other commodities, under agroecological situations where those commodities offer alternative uses of arable land.

The substantial economic benefits estimated in this study from research on the two major cereals of the CGIAR system—rice and wheat—lend strong support for the high priority they have been accorded in the system's research portfolio. The suggestion of TAC (1985) to reduce the share of these crops in future research resource allocations would seem to imply significant reductions in the expected level of economic benefits from the CGIAR system. The reasons for this seem to merit further analysis, at least in the light of the results presented in this study. For commodities such as sorghum, coconuts, groundnuts, sheep and goats there would have to be much larger differences in the unit-cost-savings expected from research before the economic benefits would exceed those expected from research on commodities such as rice, potato, wheat, sugar, maize, and sweet potato.

The contribution of spillover effects from regions where research is conducted to other regions with similar agroecologies and infrastructure were shown to be substantial. Between 65 and 82% of total international benefits from agricultural research on the 12 commodities considered so far were estimated to come from such spillovers. Policymakers in national agricultural research systems no doubt ignore likely spillover effects to other countries/regions in making decisions about the level and allocation of their own research resources. This is likely to result in under-investment and/or different patterns of research investment by these countries. In view of this, multilateral and bilateral agencies supporting agricultural research, both private and public, may play a key role in helping to ensure that their research resources are deployed in a manner which exploits spillover effects where possible. In this way the returns to incremental investments in research can be enhanced. The dramatic increase in external support for national agricultural research in developing countries in recent years can be expected to redress some of the apparent underinvestment evidenced earlier, but may lead to declining marginal rates of return in future. Explicit consideration of spillovers by external agencies may offer a means of rationalising their continuing support for national agricultural research in developing countries.

In alluding to the spillover phenomenon it is not suggested that multilateral and bilateral agencies in any way usurp the authority of national agricultural research systems or substitute for them. Rather the implication is that international and national research systems are complementary and that there are likely to be considerable rewards from encouraging mechanisms which enhance the flow of information among them. The proliferation of research networks in recent years would appear to be a manifestation of the realisation that there are mutual benefits to be gained from exploiting such research spillovers.

The absolute economic benefits among commodities and regions presented in the paper are of less interest than the relativities among them in making judgments about the allocation of international research resources. With suitable modifications the framework described in this study can be utilised by individual national agricultural research systems, as outlined by, for example, Beck et al. (1986).

Much of the information used in the foregoing analysis is the result of expert judgments. These should be viewed as initial estimates to be revised as a result of further discussions. The information has been collected in relation to an aggregate level of analysis and therefore simplifying assumptions have sometimes been incorporated. The framework can be adapted to be applicable at the individual program and possibly the project level. Such applications should provide useful feedback as to the appropriateness of some of the aggregate estimates that have been used. In addition, individual project-level application of the framework will facilitate more realistic assumptions about factors which determine the size of unit-cost changes from research and the research costs required to achieve them. This is not to say that the information generated by this framework can replace the crucial scientific judgment required for individual project assessment. Rather this information has a role to play in generating questions related to whether, irrespective of scientific excellence, research on a particular commodity in a particular region should be contemplated. If it is judged to be relevant, it may indicate what unit-cost reduction would be required to justify consideration of specific projects. Consideration of these questions at the individual project level could provide information on the critical parameters, which could then be used in revised assessments and perhaps result in reconsideration of aggregate priorities.

Appendix A

A Partial Equilibrium Multi-Country Model for Agricultural Research Evaluation: Derivation of Formulae

This section briefly outlines, in equation form, the model used to develop the benefit evaluation formulae. As far as possible the same notation as used by Edwards and Freebairn (1984) is adopted to facilitate comparison with their formulae.

A.1 Basic Model Before Research

Demand Functions:

Country/Region 1: $Q_{d1t} = a_{1t} - b_1 P_{1t}$ (A.1)
Country/Region 2: $Q_{d2t} = a_{2t} - b_2 P_{2t}$ (A.2)
Country/Region *i*: $Q_{dit} = a_{it} - b_i P_{it}$ (A.3)
Country/Region *N*: $Q_{dNt} = a_{Nt} - b_N P_{Nt}$ (A.4)

where:

- N is the total number of production/consumption regions for the commodity of interest.
- Q_{dit} is the quantity consumed in country/region '*i*' ($i = 1 \ldots N$) in time period '*t*' ($t = 1 \ldots T$).
- P_{it} is the domestic price of the commodity in country/region '*i*' in period '*t*'.
- a_{it} and b_i are the intercept and slope parameters of demand in country/region '*i*'.

Supply Functions:

Country/Region 1: $Q_{s1t} = \alpha_{1t} + \beta_1 P_{1t}$ (A.5)
Country/Region 2: $Q_{s2t} = \alpha_{2t} + \beta_2 P_{2t}$ (A.6)
Country/Region *i*: $Q_{sit} = \alpha_{it} + \beta_i P_{it}$ (A.7)
Country/Region N: $Q_{sNt} = \alpha_{Nt} + \beta_N P_{Nt}$ (A.8)

where:

- Q_{sit} is the quantity of the commodity produced in country/region '*i*' in time period '*t*'.
- α_{it}, β_i are the intercept and slope parameters of supply in country/region '*i*' in period '*t*'.

Transport Costs Between Countries

In the Edwards and Freebairn model it was assumed that

$$P_{wt} = P_{1t} = P_{2t} = P_{it} = P_{Nt}$$

where P_{wt} is the world price in period '*t*'. This assumes therefore that the price paid by consumers in importing countries is the same as that received by producers in the exporting country. This assumption can result in over-estimation of the benefits to research (Davis 1984).

To correct for this possible bias in the model, and yet to keep it relatively simple, the following assumptions are made. A central marketing point is specified where it is assumed that the world price, P_{wt}, is established. The transport costs from this location to each country are determined and it is assumed that these services have an elastic supply over the ranges of change in output considered. The before and after research trade patterns are assumed to remain basically unchanged.

It is necessary, therefore, to distinguish between net exporting and net importing countries. If it is assumed there are '*n*' exporting countries and '*N–n*' importing countries then the following domestic prices will apply.

$$P_{ht} = P_{wt} - z_h \qquad \text{(A.9)}$$

where: z_h is the transport cost from exporting country '*h*' to the world market location and $h = 1 \ldots n$.

and

$$P_{jt} = P_{wt} + z_j \qquad \text{(A.10)}$$

where: z_j is the transport cost from the world market location to importing country '*j*' ($j = n + 1 \ldots N$).

Exchange Rate Differences Between Countries

In a multi-country environment the quantity supplied to or demanded from the world market by any individual country will depend, among other things, on the value of that country's currency relative to all other countries supplying or demanding the commodity. A change in this exchange rate results in the commodity from that country becoming relatively more or less expensive. Consequently more or less will be supplied to the world market in the case of an exporting country or demanded if an importer.

If exchange rate differences are ignored in the type of model used here, and therefore implicitly assumed to be equal, biased estimates of the benefits of research may result (Davis 1984). The 'world' price of a commodity is usually recorded or quoted in terms of a single currency, most often $US. In this model the following equation is used to convert this world price into domestic currency prices for each production/consumption region:

$$P_{it} = e_{it} P_{wt} \qquad (A.11)$$

where e_{it} is the exchange rate between country 'i' and the currency used to record world prices. For example, if world prices are measured in $US and country '$i$' was Australia then in January 1986 $e_{it} = 1.4$ ($US1.00 = $A1.4). This exchange rate is assumed to be unchanged by the impact of research.

P_{it} are the commodity prices in domestic currency units.

Excess Supply Functions

To determine the equilibrium price in the world market and the associated domestic prices in each country the excess supply functions for exporting countries and excess demand functions for importing countries need to be specified. These functions are expressed in terms of P_w and allow for transport costs and exchange rate differences. For exporting country 'h' equations (A.9) and (A.11) can be combined to give

$$P_{ht} = e_{ht} P_{wt} - e_{ht} z_h \qquad (A.12)$$

which is the export parity price in country 'h'.

The excess supply for country 'h' can then be found from equations (A.3) and (A.7) as

$$\begin{aligned} Q_{esht} &= Q_{sht} - Q_{dht} \\ &= (\propto_{ht} - a_{ht}) + (\beta_h + b_n) P_{ht} \end{aligned} \qquad (A.13)$$

Expressed in terms of world prices by substituting equation (A.12) gives:

$$\begin{aligned} Q_{esht} = (\propto_{ht} - a_{ht}) &+ e_{ht}(\beta_h + b_h) P_{wt} \\ &- e_{ht}(\beta_h + b_h) z_h \end{aligned} \qquad (A.14)$$

Excess Demand Functions

The equivalent excess demand function for importing country 'j' is found in a similar fashion. The domestic price adjusted for transport costs and exchange rate differences is found from equations (A.10) and (A.11) as

$$P_{jt} = e_{jt} P_{wt} + e_{jt} z_j \qquad (A.15)$$

which is the import parity price in country 'j'.

The excess demand is found from equations (A.3) and (A.7) as:

$$\begin{aligned} Q_{edjt} &= Q_{djt} - Q_{sjt} \\ &= -(\propto_{jt} - a_{jt}) - e_{jt}(\beta_j + b_j) P_{wt} \\ &\quad - e_{jt}(\beta_j + b_j) z_j \end{aligned} \qquad (A.16)$$

Equilibrium Market Conditions

The world (and domestic) market equilibrium conditions are given by equating the sum of the excess supply for exporters with the sum of the excess demands for the importers. That is

$$\begin{aligned} Q_{es,1,t} + Q_{es,2,t} + \cdots + Q_{es,n,t} \\ = Q_{ed,n+1,t} + \cdots + Q_{ed,N,t} \end{aligned}$$

which can be written as

$$\sum_{h=1}^{n} Q_{esht} = \sum_{j=n+1}^{N} Q_{edjt} \qquad (A.17)$$

As is shown in Davis (1984), by substituting equations (A.14) and (A.16) in (A.17) this gives

$$P_{wt} = \frac{\sum_{i=1}^{N} (a_{it} - \propto_{it})}{\sum_{i=1}^{N} e_{it}(\beta_i + b_i)} + \frac{\sum_{h=1}^{n} e_{ht}(\beta_h + b_h) z_h - \sum_{j=n+1}^{N} e_{jt}(\beta_j + b_j) z_j}{\sum_{i=1}^{N} e_{it}(\beta_i + b_i)} \qquad (A.18)$$

A.2 Basic Model After Research

The parallel cost-reducing effect of research undertaken in one country on itself and each other country is defined as 'k_{iy}'. That is, in the country 'y' where the research is undertaken the 'k_{yy}' is the direct effect of research on the supply of the commodity of interest. This is similar notation as in Edwards and Freebairn (1984), that is, with subscripts omitted. The 'k_{iy}'s' for all other countries therefore represent the spillover effects on output in country 'i' of research undertaken in country 'y'. In the Edwards' and Freebairn's paper these were the terms defined as 'h'.

With this notation the individual country supply functions will change, as indicated by

Edwards and Freebairn. That is, equation (A.7) now becomes

$$Q'_{siyt} = \alpha_{it} + \beta_i k_{iy} + \beta_i P'_{it} \qquad \text{(A.19)}$$

where the prime superscript is used to denote 'with research.' Q'_{siyt} is the quantity of the commodity produced in country 'i' when research is undertaken in country 'y' in the year 't'.

Under the partial equilibrium assumption other factors are not influenced by research (e.g. transport costs and exchange rates), therefore the only additional change to the 'before research' model is in the excess supply and demand functions. These now become

$$\begin{aligned} Q'_{eshyt} = & -(a_{ht} - \alpha_{ht}) + \beta_h k_{hy} \\ & + e_{ht}(\beta_h + b_h) P'_{wt} \\ & - e_{ht}(\beta_h + b_h) z_h \end{aligned} \qquad \text{(A.20)}$$

and

$$\begin{aligned} Q'_{edjyt} = & (a_{jt} - \alpha_{jt}) - \beta_j k_{jy} \\ & - e_{jt}(\beta_j + b_j) P'_{wt} \\ & - e_{jt}(\beta_j + b_j) z_j \end{aligned} \qquad \text{(A.21)}$$

As in the 'before research' model the equilibrium conditions in the world market can be used to determine the world price, P'_{wyt}, after research undertaken in country 'y'. Davis (1984) shows that this is given by

$$P'_{wyt} = \frac{\sum_{i=1}^{N} (a_{it} - \alpha_{it})}{\sum_{i=1}^{N} e_{it}(\beta_i + b_i)} - \frac{\sum_{i=1}^{N} \beta_i k_{iy}}{\sum_{i=1}^{N} e_{it}(\beta_i + b_i)} + \frac{\sum_{h=1}^{n} e_{ht}(\beta_h + b_h) z_h - \sum_{j=n+1}^{N} e_{jt}(\beta_j + b_j) z_j}{\sum_{i=1}^{N} e_{it}(\beta_i + b_i)} \qquad \text{(A.22)}$$

With this equilibrium price the export and import parity equilibrium prices can also be found as:

$$P'_{hyt} = P_{ht} - \frac{e_{ht} \sum \beta_i k_{iy}}{\sum e_{it}(\beta_i + b_i)} \qquad \text{(A.23)}$$

and

$$P'_{jyt} = P_{jt} - \frac{e_{jt} \sum \beta_i k_{iy}}{\sum e_{it}(\beta_i + b_i)} \qquad \text{(A.24)}$$

These lead to the equilibrium quantities consumed and produced in each country being given by:

— for exporting country 'h'

$$\begin{aligned} Q'_{dhyt} &= a_{ht} - b_h P_{ht} + \frac{b_h e_{ht} \sum \beta_i k_{iy}}{\sum e_{it}(\beta_i + b_i)} \\ &= Q_{dht} + \frac{b_h e_{ht} \sum \beta_i k_{iy}}{\sum e_{it}(\beta_i + b_i)} \end{aligned} \qquad \text{(A.25)}$$

and

$$Q'_{shyt} = Q_{sht} + \beta_h k_{hy} + \frac{b_h e_{ht} \sum \beta_i k_{iy}}{\sum e_{it}(\beta_i + b_i)} \qquad \text{(A.26)}$$

— for importing country 'j'

$$Q'_{djyt} = Q_{djt} + \frac{b_j e_{jt} \sum \beta_i k_{iy}}{\sum e_{it}(\beta_i + b_i)} \qquad \text{(A.27)}$$

and

$$Q'_{sjyt} = Q_{sjt} + \beta_j k_{jy} - \frac{\beta_j + e_{jt} \sum \beta_i k_{iy}}{\sum e_{it}(\beta_i + b_i)} \qquad \text{(A.28)}$$

It can be seen that apart from the subscript denoting an importer or exporter these formulae are the same. It is also noticed that on the basis of the assumption of a perfectly elastic supply of transport services the change in consumption and production due to research is unaffected by transport costs.

A.3 Formulae for Calculating Annual Research Benefits

The formulae for consumer benefits, producer benefits, annual national benefits and world benefits can be derived in the same way as Edwards and Freebairn (1984). Expressed in world prices of the commodities using the expression in equation A.11 we have the following derivations:[1]

Consumer Benefits from Research Undertaken in Country 'y' (Standard Currency)

$$G^w_{cfyt} = \frac{Q_{dft} \sum \beta_i k_{iy}}{\sum e_{it}(\beta_i + b_i)} + \frac{b_f e_{ft} \left(\sum \beta_i k_{iy}\right)^2}{2\left(\sum e_{it}(\beta_i + b_i)\right)^2} \quad \text{(A.29)}$$

Producer Benefits (Standard Currency)

$$G^w_{gfyt} = \left(\frac{k_{fy}}{e_{ft}} - \frac{\sum \beta_i k_{iy}}{\sum e_{it}(\beta_i + b_i)} \right) Q_{sft} + \frac{\beta_f e_{ft}}{2} \left(\frac{k_{fy}}{e_{ft}} - \frac{\sum \beta_i k_{iy}}{\sum e_{it}(\beta_i + b_i)} \right)^2 \quad \text{(A.30)}$$

National Benefits from Research Undertaken in Country 'y' (Standard Currency)

$$G^w_{fyt} = \frac{k_{fy}}{e_{ft}} Q_{sft} + \frac{(Q_{dft} - Q_{sft}) \sum \beta_i k_{iy}}{\sum e_{it}(\beta_i + b_i)} + \frac{b_f e_{ft} \left(\sum \beta_i k_{iy}\right)^2}{2\left(\sum e_{it}(\beta_i + b_i)\right)^2} + \frac{\beta_f e_{ft}}{2} \left(\frac{k_{fy}}{e_{ft}} - \frac{\sum \beta_i k_{iy}}{\sum e_{it}(\beta_i + b_i)} \right)^2 \quad \text{(A.31)}$$

[1]To convert the formulae in A.29–A.33 to world prices in national currency terms they should be multiplied by the exchange rate, e_{ft} for each country 'f', ($f = 1.2 \ldots N$).

Total International Benefits (Standard Currency)

The total international benefits from the research effort in country 'y' resulting in the set of cost-reducing effects 'k_{iy}' ($i = 1 \ldots N$) is the sum of the national benefits. That is:

$$G^w_{yt} = G_{y1t} + G_{y2t} + \cdots + G_{yft} + \cdots G_{ynt}$$

$$= \sum_{f=1}^{N} G_{yft}$$

$$= \sum_{f=1}^{N} \frac{k_{fy}}{e_{ft}} Q_{sft} + \sum_{f=1}^{N} \frac{(Q_{dft} - Q_{sft}) \sum_{i=1}^{N} \beta_i k_{iy}}{\sum_{i=1}^{N} e_{it}(\beta_i + b_i)} + \sum_{f=1}^{N} \frac{b_f e_{ft} \left(\sum_{i=1}^{N} \beta_i k_{iy}\right)^2}{2\left(\sum_{i=1}^{N} e_{it}(\beta_i + b_i)\right)^2} + \sum_{f=1}^{N} \frac{\beta_f e_{ft}}{2} \left(\frac{k_{fy}}{e_{ft}} - \frac{\sum_{i=1}^{N} \beta_i k_{iy}}{\sum_{i=1}^{N} e_{it}(\beta_i + b_i)} \right)^2 \quad \text{(A.32)}$$

Now since $\sum_{f=1}^{N} (Q_{dft} - Q_{sft}) = 0$, that is, total world supply less world demand is zero, then

$$G^w_{yt} = \sum_{f=1}^{N} \frac{k_{fy}}{e_{ft}} Q_{sft} + \sum_{f=1}^{N} \frac{b_f e_{ft} \left(\sum_{i=1}^{N} \beta_i k_{iy}\right)^2}{2\left(\sum_{i=1}^{N} e_{it}(\beta_i + b_i)\right)^2} + \sum_{f=1}^{N} \frac{\beta_f e_{ft}}{2} \left(\frac{k_{fy}}{e_{ft}} - \frac{\sum_{i=1}^{N} \beta_i k_{iy}}{\sum_{i=1}^{N} e_{it}(\beta_i + b_i)} \right)^2 \quad \text{(A.33)}$$

Appendix B

The Impact of a Subsidy on Estimation of the Social Benefits from Research

Alston et al. (1986) show in detail the implications of various forms of price distortions for research evaluation. Their main conclusions can be illustrated using a simplified non-traded good model. Figure B.1 provides a simple representation of an output subsidy for this situation. Without a subsidy the supply of the commodity is represented by S. With a per unit subsidy of *'af'* the supply shifts to the right S_s. That is, farmers will produce increased output levels at the same market price since the gross price they now receive is the market price plus the subsidy. The equilibrium output with a subsidy increases from Q to Q_s.

If research results in a shift in the original supply, that is, from S to S', then this will also shift the subsidised supply by the same distance, that is, from S_s to S'_s. With no subsidy the gross benefits from research are given by the area *'abce'*. With subsidy in place the gross benefits from research are given by the area *'fghj'*. It can be shown that the latter area is larger by the area *'kgim'*. If the

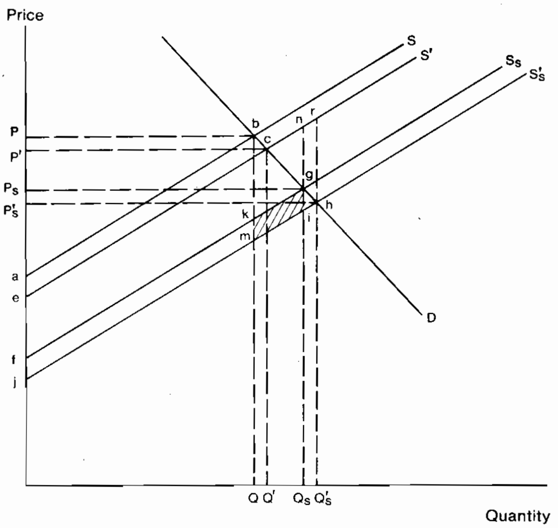

Fig. B.1. Simple non-traded good illustration of impact of a subsidy on research benefits.

procedures used to estimate these areas ignore subsidy distortions to prices, estimates of the benefits of research will be higher for a subsidised commodity as opposed to an unsubsidised commodity. The opposite applies to a taxed commodity.

As Alston et al. show, this difference exists because the 'with subsidy' case estimates 'private' rather than 'social' benefits to research. To find 'social' benefits it is necessary to subtract the cost of additional subsidy payments on the increased output, $Q'_s - Q_s$, due to research. It can be shown that this additional subsidy payment is equivalent to the area *'nhri'* in Fig. B.1. It can also be shown that this additional subsidy payment under the parallel supply shift assumption, is the same as the area *'kgim'*. Therefore the net social benefits from research are the same with or without the subsidy as long as the social cost of the additional subsidy payments are subtracted when a subsidy is paid.

While the total social benefits of research are not affected by distortions to commodity prices caused by commodity subsidies or taxes, the distribution of these benefits is influenced substantially. This conclusion stems from the considerable redistribution that can result from the subsidy policy.

The annual additional subsidy payments in country *'h'*, for the internationally traded good case, due to the increased output as a result of research is given by:

$$(Q'_{shyt} - Q_{sht})\, S_{ht} = \left[\beta_h k_{hy} + \frac{\beta_h e_{ht} \sum_{i=1}^{N} \beta_i k_{iy}}{\sum_{i=1}^{N} e_{it} (\beta_i + b_i)}\right] S_{ht} \qquad \text{(B.1)}$$

where S_{ht} is the subsidy rate per unit of output. In the case of a commodity tax this will be negative.

Revised equations to take account of subsidies and taxes are as follows:

Present Value of Gross International Benefits with Subsidies or Taxes

$$E[PV(G_y^w)]^* = E[PV(G_y^w)] - \sum_{t=1}^{T} \sum_{f=1}^{N} \frac{p_{yt}\,\beta_f}{(1+r)^t} \left[x_{ft}\,k_{fy} + \frac{e_{ft} \sum_{i=1}^{N} \beta_i\, x_{it}\, k_{iy}}{\sum_{i=1}^{N} e_{it}\,(\beta_i + b_i)} \right] \frac{S_{ft}}{e_{it}} \quad \text{(B.2)}$$

Present Value of National Benefits for Country/Region 'f' with Subsidies or Taxes

$$E[PV(G_{yf})]^* = E[PV(G_{yf}^w)] - \sum_{t=1}^{T} p_{yt}\,\beta_f \left[x_{ft}\,k_{fy} + \frac{e_{ft} \sum_{i=1}^{N} \beta_i\, x_{it}\, k_{iy}}{\sum_{i=1}^{N} e_{it}\,(\beta_i + b_i)} \right] \frac{S_{ft}}{e_{it}} \quad \text{(B.3)}$$

Present Value of Consumer benefits for Country/Region 'f' with Subsidy or Tax

As in text equation 3, that is, not changed by subsidy or tax. However, since the prices and quantities used are affected by the subsidies or taxes imposed, these values will not be the same as would apply if these subsidies or taxes were all removed.

Present Value of Producer Benefits for Country/Region 'f' with Subsidy or Tax

As in text equation 4, for the same reason as consumer benefits above.

Present Value of Additional Government Expenditures (Revenues) for Country/Region 'f' due to Research Impact

$$E[PV(G_{gyf})]^* = -\sum_{t=1}^{T} p_{yt}\,\beta_f \left[x_{ft}\,k_{fy} + \frac{e_{ft} \sum_{i=1}^{N} \beta_i\, x_{it}\, k_{iy}}{\sum_{i=1}^{N} e_{it}\,(\beta_i + b_i)} \right] \frac{S_{ft}}{e_{it}} \quad \text{(B.4)}$$

Notice that this government expenditure is negative for $S_{ft} > 0$, that is, a subsidy payment, but will be positive if $S_{ft} < 0$ which indicates a government tax on the commodity.

There are several important implications for this additional component of the framework. For example, due to the possibility of spillover effects of research, government expenditures in one country can be influenced significantly by research undertaken in other countries. This has potentially important implications if the distributive effects of research are important to allocators of research funds.

To estimate the gross social benefits of research when subsidy or tax policies exist, detailed knowledge of the subsidy and tax levels for all commodities and regions/countries to be studied are required.

Appendix C

Fortran Computer Program for Agricultural Research Priority Assessment*

* The program as listed has been adapted to run on an IBM AT microcomputer using IBM's Professional Fortran software package. A diskette of this program plus the data used in the analysis for each commodity is available from the authors at a nominal charge to cover the cost of materials and handling.

```
C   THIS PROGRAM USES A PARTIAL EQUILIBRIUM MULTI-COUNTRY TRADE MODEL
C   TO COMPUTE THE EXPECTED INTERNATIONAL AND NATIONAL BENEFITS AND
C   THEIR DISTRIBUTION RESULTING FROM FUNDING RESEARCH IN A PARTICULAR
C   COMMODITY IN DIFFERENT COUNTRIES/REGIONS. AN ORIGINAL VERSION OF
C   THE PROGRAM WAS WRITTEN BY ROBIN DONALDSON OF IFPRI FOR A
C   MAINFRAME COMPUTER. THIS VERSION HAS BEEN ADAPTED AT ACIAR FOR
C   USE ON AN IBM AT MICROCOMPUTER USING IBM'S PROFESSIONAL FORTRAN
C   SOFTWARE PACKAGE.
      COMMON / PARMS / NPC,NCC,NT,NYRS,LAG1,LAG2,R
      COMMON / DATAIN / PS(50),RA(50),CSTSAV(50),QP(50),QC(50),
     X                   PRICE(50),EXRT(50),ES(50),ED(50),FK(40,50),
     X                   PSI(50),IFLAG(50),FKIN(40,50)
      COMMON /DATCOM / BETA(50),B(50),DEN,BETAE(50),BE(50),
     X                 BETAXK(40)
C
      CALL RDPRMS
      CALL RDDATA
      CALL CLC1
      CALL CLC2
      CALL CLCGP
      CALL OUTPT
C
      STOP
      END
C.....................................................................
      SUBROUTINE RDPRMS
C
      COMMON / PARMS / NPC,NCC,NT,NYRS,LAG1,LAG2,R
C    READ PARAMETERS
C
C    READ NUMBER OF PRODUCTION REGIONS/COUNTRIES DOING RESEARCH
       WRITE (6,100)
       READ (5,200) NPC
C
C    READ NUMBER OF OTHER PRODUCTION AND CONSUMPTION REGIONS
       WRITE (6,300)
       READ (5,200) NCC
C
C     TOTAL NUMBER OF REGIONS/COUNTRIES
       NT = NPC + NCC
C
C     NUMBER OF YEARS (PLANNING HORIZON)
       WRITE (6,400)
       READ (5,200) NYRS
C
C     LAG - YEARS BETWEEN START OF RESEARCH AND ADOPTION OF RESULTS
10     WRITE (6,500)
       READ (5,200) LAG1
       IF (LAG1.LT.1.OR.LAG1.GT.NYRS) GO TO 10
20     WRITE (6,550)
       READ (5,200) LAG2
       IF (LAG2.LT.1.OR.LAG2.GT.NYRS) GO TO 20
C
C     DISCOUNT RATE
       WRITE (6,600)
       READ (5,700) R
       R = (R/100.) + 1.0
C
       RETURN
```

```
C
100     FORMAT (' NO. OF PRODN. REGIONS/COUNTRIES: ')
200     FORMAT (I4)
300     FORMAT (' NO. OF OTHER PRODN. AND CONS. REGIONS: ')
400     FORMAT (' NO. OF YEARS: ')
500     FORMAT (' LAG (REGION WHERE RESEARCH UNDERTAKEN): ')
550     FORMAT (' LAG (ALL OTHER REGIONS ): ')
600     FORMAT (' DISCOUNT RATE (Include decimal) (%): ')
700     FORMAT (F4.2)
        END
C
C
C.......................................................................
C
         SUBROUTINE RDDATA
C
        CHARACTER*10 FILNAM
        CHARACTER*12 CNTNAM(50)
        CHARACTER*20 GRPNAM(0:8)
        COMMON / PARMS / NPC,NCC,NT,NYRS,LAG1,LAG2,R
        COMMON / NAMES / CNTNAM,GRPNAM
        COMMON / DATAIN / PS(50),RA(50),CSTSAV(50),QP(50),QC(50),
     X                   PRICE(50),EXRT(50),ES(50),ED(50),FK(40,50),
     X                    PSI(50),IFLAG(50),FKIN(40,50)
        COMMON / DATCOM / BETA(50),B(50),DEN,BETAE(50),BE(50),
     X                   BETAXK(40)
        DIMENSION Z(10)
C
C     READ DATA FOR ALL COUNTRIES - EXCEPT SPILLOVER EFECTS
        WRITE (6,100)
        READ (5,200) FILNAM
        OPEN (UNIT=3,FILE=FILNAM)
C
        DO 10 I=1,NT
        READ (3,300) CNTNAM(I),(Z(J),J=1,10),GRP
        PS(I)      =Z(1)
        PSI(I)     =Z(2)
        PS(I)      = PS(I) + PSI(I)
        RA(I)      = Z(3)
        CSTSAV(I)  =Z(4)
        QP(I)      =Z(5)
        QC(I)      =Z(6)
        PRICE(I)   =Z(7)
        EXRT(I)    =Z(8)
        ES(I)      =Z(9)
        ED(I)      =Z(10)
        IFLAG(I)   = GRP
10      CONTINUE
C
C     READ SPILLOVER EFFECTS MATRIX (PRODN. REGIONS X TOTAL REGS)
        WRITE (6,400)
        READ (5,200) FILNAM
        OPEN (UNIT=4,FILE=FILNAM)
C
        DO 20 I=1,NT
        READ (4,*) (FKIN(J,I),J=1,NPC)
20      CONTINUE
C
C   ADJUST DIRECT SPILLOVERS BY PROBABILITY OF SUCCESS TO GIVE
C   ADAPTIVE SPILLOVERS
C
        DO 40 JF=1,NT
        PSAR = PS(JF) - PSI(JF)
```

```
C
         DO 30 I=1,NPC
         FK(I,JF) = 1.0
         IF (I.EQ.JF) GO TO 30
         FK(I,JF) = FKIN(I,JF) * PSAR
30      CONTINUE
40      CONTINUE
C
        RETURN
C
50      WRITE (6,600)
        STOP
C
100     FORMAT (' NAME OF INPUT FILE FOR ALL COUNTRIES: ')
200     FORMAT (A10)
300     FORMAT (A12,1X,3(F3.2,1X),F5.1,1X,2(F8.1,1X),F6.1,1X,F3.1,1X,
     X          2(F4.2,1X),F4.1)
400     FORMAT (' NAME OF INPUT FILE OF SPILLOVER EFFECTS: ')
500     FORMAT (40F12.3)
600     FORMAT (' PREMATURE END OF FILE')
        END
C
C
C...................................................................
C
        SUBROUTINE CLC1
C
        COMMON / PARMS / NPC,NCC,NT,NYRS,LAG1,LAG2,R
        COMMON / DATAIN / PS(50),RA(50),CSTSAV(50),QP(50),QC(50),
     X                    PRICE(50),EXRT(50),ES(50),ED(50),FK(40,50),
     X                    PSI(50),IFLAG(50),FKIN(40,50)
        COMMON / DATCOM / BETA(50),B(50),DEN,BETAE(50),BE(50),
     X                    BETAXK(40)
C
C   LOOP THROUGH ALL REGIONS AND DO SOME PRELIMINARY CALCULATIONS
        DEN = 0.0
C
        DO 10 I=1,NT
        BETA(I)=0.
        B(I)=0.
C
C   BETA AND B
        IF (PRICE(I).EQ.0.) GO TO 5
        BETA(I) = (ES(I) * QP(I))/PRICE(I)
5       CONTINUE
        B(I)    = (ED(I) * QC(I))/PRICE(I)
C
C   SUM OF E(BETA + B)
        DEN = DEN + (EXRT(I) * (BETA(I) + B(I)))
C
C   BETA *E AND B*E
        BETAE(I)= BETA(I)  * EXRT(I)
        BE(I)   = B(I)     * EXRT(I)
C
10      CONTINUE
C
C
        RETURN
        END
C
C
```

```
C...........................................................
C
      SUBROUTINE CLC2
C
      COMMON / PARMS / NPC,NCC,NT,NYRS,LAG1,LAG2,R
      COMMON / DATAIN / PS(50),RA(50),CSTSAV(50),QP(50),QC(50),
     X                  PRICE(50),EXRT(50),ES(50),ED(50),FK(40,50),
     X                  PSI(50),IFLAG(50),FKIN(40,50)
      COMMON / DATCOM / BETA(50),B(50),DEN,BETAE(50),BE(50),
     X                  BETAXK(40)
C
C   COMPUTE SUM OF BETA(I)*X(I)*K(I) FOR EACH PRODUCTION REGION
C
      DO 20 I = 1,NPC
      Y = 0.0
      BETAXK(I)=0.0
      DO 10 J = 1,NT
      Y = Y + (BETA(J) * RA(J) * FK(I,J))
10    CONTINUE
      BETAXK(I) = Y * CSTSAV(I)
CCC      TYPE 990, Y, BETAXK(I)
CCC990   FORMAT (1X,2F15.2)
20    CONTINUE
C
      RETURN
      END
C
C
C.................................................................
      SUBROUTINE CLCGP
C
      INTEGER T
      CHARACTER*12 CNTNAM(50)
      CHARACTER*20 GRPNAM(0:8)
      COMMON / PARMS / NPC,NCC,NT,NYRS,LAG1,LAG2,R
      COMMON / NAMES / CNTNAM,GRPNAM
      COMMON / DATAIN / PS(50),RA(50),CSTSAV(50),QP(50),QC(50),
     X                  PRICE(50),EXRT(50),ES(50),ED(50),FK(40,50),
     X                  PSI(50),IFLAG(50),FKIN(40,50)
      COMMON / DATCOM / BETA(50),B(50),DEN,BETAE(50),BE(50),
     X                  BETAXK(40)
      COMMON / RSLTS / BENP(50,40,2),BENC(50,40,2),BENN(50,40,2),
     X                TOTBEN(40,2), SPLOVR(40,2)
C
      DO 911 I=1,40
      DO 911 J=1,2
911   TOTBEN(I,J)=0.0
C
      DO 912 I=1,50
      DO 912 J=1,40
      DO 912 K=1,2
      BENP(I,J,K) =0.0
      BENC(I,J,K) =0.0
912   BENN(I,J,K) =0.0
C
C*TWO ITERATIONS OF COMPUTATIONS - ONE FOR TOTAL INTERNATIONAL
C* BENEFITS AND ONE FOR BENEFITS RESULTING FROM ACIAR INCREMENT
C
      DO 80 ITER = 1,2
C
```

```
C****A. FOR EACH REGION UNDERTAKING RESEARCH
C
       DO 70 I = 1,NPC
C
C    USE APPROPRIATE PROBABILITY OF SUCCESS
       IF (ITER.EQ.1) TPS = PS(I)
       IF (ITER.EQ.2) TPS = PSI(I)
C
C
C******B. COMPUTE PRODUCER BENEFITS - TO ALL REGIONS
C
       DO 20 JF = 1,NT
C
C NOTE ALL OF THE EQUATIONS EXCEPT PRESENT VALUE CALCULATION NEEDS
C TO BE COMPUTED ONLY ONCE FOR EACH PRODUCER REGION , UNLESS DATA
C VARIES OVER THE PLANNING HORIZON
C
       IF (QP(JF).EQ.QC(JF)) GO TO 110
C
       XK = (RA(JF)*CSTSAV(I)*FK(I,JF))/EXRT(JF)
       A  = XK - (BETAXK(I)/DEN)
       GP = ((QP(JF)*A) + ((BETAE(JF)/2.0)*(A**2))) * TPS
       GO TO 120
C
C  COUNTRY / REGION 'JF' IS A CLOSED ECONOMY - USE DIFFERENT EQUATION
110    XK =  RA(JF) * CSTSAV(I) * FK(I,JF) * B(JF)
       TB = BETAE(JF) + BE(JF)
       GP = 0.
       IF (TB.EQ.0.) GO TO 120
       A = XK/TB
       GP = ((QP(JF)*A) + ((BETA(JF)/2.0)*(A**2))) * TPS
C
C
C********* COMPUTE PRESENT VALUE
120    CONTINUE
        LAG = LAG1
        IF (I.NE.JF) LAG = LAG2
        G = 0.
        DO 10 T = LAG,NYRS
        G = G + (GP/(R**T))
10     CONTINUE
       BENP(JF,I,ITER) = G/1000.
C
20     CONTINUE
C
C
C***** C. COMPUTE CONSUMER BENEFITS - TO ALL REGIONS
C
       DO 40 JF = 1,NT
C   SEE NOTE UNDER B ABOVE
C
       IF (QP(JF).EQ.QC(JF)) GO TO 130
C
       A = BETAXK(I)/DEN
       GC = ((QC(JF)*A) + ((BE(JF)/2.0)*(A**2))) * TPS
       GO TO 140
C
```

```
C   COUNTRY / REGION 'JF' IS A CLOSED ECONOMY - USE DIFFERENT EQ.
130     XK = RA(JF) * CSTSAV(I) * FK(I,JF) * BETA(JF)
        TB = BETAE(JF) + BE(JF)
        GC = 0.
        IF (TB.EQ.0.) GO TO 140
        A = XK/TB
        GC = ((QC(JF)*A) + ((B(JF)/2.0)*(A**2))) * TPS
C
C********** COMPUTE PRESENT VALUE
140     CONTINUE
        LAG = LAG1
        IF (I.NE.JF) LAG = LAG2
        G =0.0
        DO 30 T=LAG,NYRS
        G = G + (GC/(R**T))
30      CONTINUE
        BENC(JF,I,ITER) = G/1000.
C
40      CONTINUE
C
C******* D. NATIONAL BENEFITS
        DO 60 JF=1,NT
        BENN(JF,I,ITER) = BENP(JF,I,ITER) + BENC(JF,I,ITER)
        TOTBEN(I,ITER)  = TOTBEN(I,ITER) + BENN(JF,I,ITER)
60      CONTINUE
C
        SPLOVR(I,ITER) = TOTBEN(I,ITER) - BENN(I,I,ITER)
C
70      CONTINUE
C
80      CONTINUE
C
        RETURN
        END
C
C
C.............................................................
C
        SUBROUTINE OUTPT
C
        CHARACTER*12 CNTNAM(50)
        CHARACTER*20 GRPNAM(0:8)
        CHARACTER*24 CMDNAM
        CHARACTER*10 FILNAM
        COMMON / PARMS / NPC,NCC,NT,NYRS,LAG1,LAG2,R
        COMMON / DATAIN / PS(50),RA(50),CSTSAV(50),QP(50),QC(50),
     X                  PRICE(50),EXRT(50),ES(50),ED(50),FK(40,50),
     X                  PSI(50),IFLAG(50),FKIN(40,50)
        COMMON / NAMES / CNTNAM,GRPNAM
        COMMON / RSLTS / BENP(50,40,2),BENC(50,40,2),BENN(50,40,2),
     X                  TOTBEN(40,2),SPLOVR(40,2)
        GRPNAM(0)=   'ALL DEVELOPING      '
        GRPNAM(1)=     'AFRICA              '
        GRPNAM(2)=     'ASIA                '
        GRPNAM(3)=     'LATIN AMERICA       '
        GRPNAM(4)=     'OCEANIA             '
        GRPNAM(5)=     'W ASIA/N AFRICA     '
        GRPNAM(6)=     'OTHER DEVELOPING    '
        GRPNAM(7)=     'DEVELOPED           '
        GRPNAM(8)=     'ALL REGIONS         '
```

```
C
      WRITE (6,100)
      READ (5,200) CMDNAM
      WRITE (6,300)
      READ (5,400) FILNAM
      OPEN (UNIT=2,FILE=FILNAM)
      WRITE(6,790)
      WRITE(6,791)
      WRITE(6,792)
      READ(5,793)IPICK
790   FORMAT(4(/),1X,' THIS PROGRAM HAS BEEN WRITTEN TO ALLOW FOR A '
     X           /1X,' CHOICE OF OUTPUT POSSIBILITIES. THESE ARE: ',/)
791   FORMAT(1X,'1. ORIGINAL DATA                     :'
     X           /1X,'2. DETAILED OUTPUT/COUNTRIES     :'
     X           /1X,'3. SUMMARY OUTPUT                :'
     X           /1X,'4. COMBINATION OF 1 & 2          :'
     X           /1X,'5. COMBINATION OF 1 & 3          :'
     X           /1X,'6. COMBINATION OF 2 & 3          :'
     X           /1X,'7. ALL COMBINATIONS              :'
     X           /1X,'8. TERMINATE SESSION             :',/)
792   FORMAT(1X,'ENTER YOUR CHOICE <1,2,3, ETC>  :')
793   FORMAT(I1)
C
C
      GO TO (1351,1352,1353,1354,1355,1356,1357,1358)IPICK
1351  CALL LSTDAT(CMDNAM)
      GO TO 1358
1352  CALL DETAIL(CMDNAM)
      GO TO 1358
1353  CALL SUMRY(CMDNAM)
      GO TO 1358
1354  CALL LSTDAT(CMDNAM)
      CALL DETAIL(CMDNAM)
      GO TO 1358
1355  CALL LSTDAT(CMDNAM)
      CALL SUMRY (CMDNAM)
      GO TO 1358
1356  CALL DETAIL(CMDNAM)
      CALL SUMRY (CMDNAM)
      GO TO 1358
1357  CALL LSTDAT(CMDNAM)
      CALL DETAIL(CMDNAM)
      CALL SUMRY (CMDNAM)
      GO TO 1358
1358  RETURN
C
C
C
100   FORMAT ('  NAME OF COMMODITY : ')
200   FORMAT (A24)
300   FORMAT (' NAME OF PRINT FILE: ')
400   FORMAT (A10)
      END
C
C
```

```
C.........................................................
C
C
      SUBROUTINE DETAIL (CMDNAM)
C
      CHARACTER*24 CMDNAM
      CHARACTER*12 CNTNAM(50),C(40)
      CHARACTER*20 GRPNAM(0:8)
      CHARACTER*10 BLANK,CX*1
      COMMON / PARMS / NPC,NCC,NT,NYRS,LAG1,LAG2,R
      COMMON / DATAIN / PS(50),RA(50),CSTSAV(50),QP(50),QC(50),
     X                  PRICE(50),EXRT(50),ES(50),ED(50),FK(40,50),
     X                  PSI(50),IFLAG(50),FKIN(40,50)
      COMMON / NAMES / CNTNAM,GRPNAM
      COMMON / RSLTS / BENP(50,40,2),BENC(50,40,2),BENN(50,40,2),
     X                  TOTBEN(40,2),SPLOVR(40,2)
      DATA BLANK /'          '/
C
C
C  RIGHT JUSTIFY COUNTRY NAMES FOR HEADINGS
      DO 5 II=1,NPC
      DO 3 JJ=1,12
      CX= CNTNAM(II)(JJ:JJ)
      IF (CX.NE.' ') GO TO 3
      L1=JJ
      L2=L1-1
      L3=12-L2
      C(II)=BLANK(1:L3)//CNTNAM(II)(1:L2)
      GO TO 5
3     CONTINUE
5     CONTINUE
C
      IFST = 1
      ILAST= 9
      WRITE(2,*)CHAR(12)
7     CONTINUE
      IF (ILAST.GT.NPC) ILAST = NPC
      WRITE (2,500) CMDNAM
      WRITE (2,600)
      WRITE (2,700) (C(J),J=IFST,ILAST)
      WRITE (2,800)
C
      WRITE (2,900) (TOTBEN(I,1),I=IFST,ILAST)
      WRITE (2,950) (SPLOVR(I,1),I=IFST,ILAST)
      WRITE (2,975) (TOTBEN(I,2),I=IFST,ILAST)
C
      WRITE (2,1000)
      DO 10 JF=1,NPC
      WRITE (2,1100) CNTNAM(JF),(BENC(JF,I,1),I=IFST,ILAST)
      WRITE (2,1200)           (BENP(JF,I,1),I=IFST,ILAST)
10    CONTINUE
C
      WRITE (2,1400)
       J= NPC + 1
      DO 20 JF = J,NT
      WRITE (2,1100) CNTNAM(JF),(BENC(JF,I,1),I=IFST,ILAST)
      WRITE (2,1200)           (BENP(JF,I,1),I=IFST,ILAST)
20    CONTINUE
C
```

```
C
        IFST = IFST + 9
        ILAST = ILAST + 9
        IF (NPC.GE.IFST) THEN
        WRITE(2,*)CHAR(12)
        GO TO 7
        ENDIF
C
        RETURN
C
500     FORMAT (1X,A24,': ASSESSMENT OF MULTI-COUNTRY RESEARCH'/
     X          1X,24('='),2X,
     X          'PRESENT VALUE OF GROSS BENEFITS AND DISTRIBUTION',
     X          ' OF GROSS BENEFITS  ($US M )'/)
600     FORMAT (35X,'REGION WHERE RESEARCH IS UNDERTAKEN'/
     X          19X,108('-'))
700     FORMAT (/19X,9(A12))
800     FORMAT (19X,108('-'))
975     FORMAT (' TOTAL BENEFITS DUE TO'/' ACIAR INCREMENT   ',9F12.1)
900     FORMAT (/' TOTAL INTERNATL.'/' BENEFITS',10X,9F12.1)
950     FORMAT (' SPILLOVER EFFECTS ',9F12.1)
1000    FORMAT (/' NATIONAL BENEFITS'/' PRODUCTION REGIONS'/1X,18('-'))
1100    FORMAT (2X,A12/8X,'- CONSUMERS',9F12.1)
1200    FORMAT (8X,'- PRODUCERS',9F12.1)
1300    FORMAT (8X,'- TOTAL     ',9F12.1)
1400    FORMAT (/' OTHER PRODUCTION AND CONSUMPTION REGIONS'/1X,40('-'))
        END
C
C
C.........................................................................
C
        SUBROUTINE LSTDAT(CMDNAM)
C
        CHARACTER*24 CMDNAM
        CHARACTER*12 CNTNAM(50)
        CHARACTER*20 GRPNAM(0:8)
        COMMON / PARMS / NPC,NCC,NT,NYRS,LAG1,LAG2,R
        COMMON / DATAIN / PS(50),RA(50),CSTSAV(50),QP(50),QC(50),
     X                    PRICE(50),EXRT(50),ES(50),ED(50),FK(40,50),
     X                    PSI(50),IFLAG(50),FKIN(40,50)
        COMMON / NAMES / CNTNAM,GRPNAM
        COMMON / RSLTS / BENP(50,40,2),BENC(50,40,2),BENN(50,40,2),
     X                   TOTBEN(40,2),SPLOVR(40,2)
        DIMENSION W(40),Z(10)
C
C    PRINT OUT DATA FOR THIS RUN
        WRITE(2,*)CHAR(12)
        WRITE (2,100) CMDNAM
C    1.  COUNTRY/REGION DATA
        WRITE (2,300)
        DO 10 I= 1,NT
        Z(1)  = PS(I)
        Z(2)  = PSI(I)
        Z(3)  = RA(I)
        Z(4)  = CSTSAV(I)
        Z(5)  = QP (I)
        Z(6)  = QC(I)
        Z(7)  = PRICE(I)
        Z(8)  = EXRT(I)
        Z(9)  = ES(I)
        Z(10)  = ED(I)
        WRITE (2,400) CNTNAM(I),(Z(J),J=1,10)
10      CONTINUE
C
```

```
C   2. PRINT OUT SPILLOVER EFFECT MATRIX
         DO 120 ITER=1,2
         WRITE(2,*)CHAR(12)
         WRITE (2,600) CMDNAM
C
         GO TO (50,60) ITER
50       WRITE (2,1000)
         GO TO 70
60       WRITE (2,1100)
70       CONTINUE
C
C
         IFST = 1
         ILAST = 22
30       CONTINUE
         IF (ILAST.GT.NPC) ILAST = NPC
         WRITE (2,700) (CNTNAM(J),J=IFST,ILAST)
         DO 40 I=1,NT
         GO TO (80,90) ITER
80       CONTINUE
         DO 811 J=1,NPC
811      W(J)=FKIN(J,I)
         GO TO 110
90       CONTINUE
         DO 812 J=1,NPC
812      W(J)=FK(J,I)
110       CONTINUE
         WRITE (2,800) CNTNAM(I),(W(J),J=IFST,ILAST)
40       CONTINUE
C
         IFST = IFST + 22
          ILAST = ILAST + 22
          IF (NPC.GE.IFST) GO TO 30
C
120       CONTINUE
C
C   3. PRINT  OUT PARAMETERS
          RATE = (R - 1.0) * 100.
          WRITE (2,900) NYRS,LAG1,LAG2,RATE
C
          RETURN
C
100       FORMAT (1X,A24,': REGION/COUNTRY DATA (EXCLUDING',
     X             ' SPILLOVER EFFECTS).'/1X,24('='))
300       FORMAT (/' COUNTRY',9X,'P(TOTAL)',4X,'P(ACIAR)',
     X             11X,'X',8X,'K(F)',7X,'PRODN',
     X             6X,'CONSUM',7X,'PRICE',11X,'E',6X,'ELAS S',6X,
     X             'ELAS D'/1X,132('-')//)
400       FORMAT (1X,A12,4F12.2,4F12.0,2F12.2)
600       FORMAT (1X,A24,': SPILLOVER EFFECT FACTORS.'
     X              /1X,24('='))
700       FORMAT (/13X,22(1X,A4)/13X,120('-')//)
800       FORMAT (1X,A12,22F5.1)
900       FORMAT (////' NUMBER OF YEARS (PLANNING HORIZON):',I4
     X              /' LAG (YEARS)-REGION DOING RESEARCH  :',I4
     X              /' LAG (YEARS)-OTHER REGIONS          :',I4
     X              /' DISCOUNT RATE (%)          :',F4.0)
1000      FORMAT (//27X,'DIRECT SPILLOVERS'/27X,17('-'))
1100      FORMAT (//27X,'ADAPTIVE SPILLOVERS'/27X,19('-'))
          END
C
C
C
C.......................................    ..........
```

```
C
C
      SUBROUTINE SUMRY (CMDNAM)
C
      CHARACTER*24 CMDNAM
      CHARACTER*12 CNTNAM(50)
      CHARACTER*20 GRPNAM(0:8)
      COMMON / PARMS / NPC,NCC,NT,NYRS,LAG1,LAG2,R
      COMMON / DATAIN / PS(50),RA(50),CSTSAV(50),QP(50),QC(50),
     X                  PRICE(50),EXRT(50),ES(50),ED(50),FK(40,50),
     X                  PSI(50),IFLAG(50),FKIN(40,50)
      COMMON / NAMES / CNTNAM,GRPNAM
      COMMON / RSLTS / BENP(50,40,2),BENC(50,40,2),BENN(50,40,2),
     X                 TOTBEN(40,2),SPLOVR(40,2)
      DIMENSION IZ(10),IZT(10,0:8),NCT(0:8)
C
      WRITE (2,*)CHAR(12)
      WRITE (2,100) CMDNAM
      WRITE (2,200)
      WRITE (2,300)
      WRITE (2,400)
      WRITE (2,500)
      WRITE (2,400)
      WRITE (2,600)
      WRITE (2,700)
      WRITE (2,800)
      WRITE (2,200)
C
C * FOR MAJOR REGIONAL GROUPINGS
C
      DO 813 I=0,8
      NCT(I)=0
      DO 813 J=1,10
813   IZT(J,I)=0
C
      DO 60 IGRP=1,7
C
      WRITE (2,850) GRPNAM(IGRP)
C
C*** FOR EACH REGION UNDERTAKING RESEARCH
C
      DO 50 I=1,NPC
C
      IF (IFLAG(I).NE.IGRP) GO TO 50
      DO 814 K=1,10
814   IZ(K)=0
C
C  TOTAL INTERNATIONAL BENEFITS
      IZ(1) = TOTBEN(I,1) + 0.5
C
C   SPILLOVER BENEFITS
      IZ(2) = SPLOVR(I,1) + 0.5
C
C  BENEFITS DUE TO ACIAR INCREMENT
      IZ(3) = TOTBEN(I,2) + 0.5
C
C
C  DISTRIBUTIVE BENEFITS FOR THIS REGION
      TB = TOTBEN(I,1)
      IF (TB.EQ.0.) GO TO 40
      TDGCB = 0.
      TDDCB = 0.
      TDGPB = 0.
      TDGPL = 0.
      TDDPB = 0.
C
```

```
C*** BENEFITS TO ALL REGIONS
C
      DO 30 JF=1,NT
C
      CB = BENC(JF,I,1)
      PB = BENP(JF,I,1)
      IF (IFLAG(JF).EQ.7) GO TO 20
C
C   DEVELOPING COUNTRY REGION
C
C     CONSUMER BENEFITS
C
      TDGCB = TDGCB + CB
C
C     PRODUCER BENEFITS
C
      IF (PB.LT.O.) GO TO 10
C
C          GAINERS
      TDGPB = TDGPB + PB
      GO TO 30
C
C          LOSERS
10    TDGPL = TDGPL + PB
      GO TO 30
C
C     DEVELOPED REGION
C
20    CONTINUE
      TDDCB = TDDCB + CB
      TDDPB = TDDPB + PB
C
30    CONTINUE
C*******
C   CONSUMER BENEFITS - DEVELOPING
C
      IZ(4) = (TDGCB/TB) * 100. + 0.5
C
C   CONSUMER BENEFITS - DEVELOPED
C
      IZ(5) = (TDDCB/TB) *100. +0.5
C
C   CONSUMER BENEFITS - TOTAL
C
      IZ(6) = ((TDGCB + TDDCB)/TB) * 100. + 0.5
C
C   PRODUCER BENEFITS - DEVELOPING GAINERS
C
      IZ(7) = (TDGPB/TB) * 100. + 0.5
C
C   PRODUCER BENEFITS - DEVELOPING LOSERS
C
      IZ(8) = (TDGPL/TB) * 100. - 0.5
C
C   PRODUCER BENEFITS - DEVELOPED
C
      IZ(9) = (TDDPB/TB) * 100. + 0.5
C
C   PRODUCER BENEFITS - TOTAL
C
      IZ(10) = ((TDGPB + TDGPL +TDDPB)/TB) * 100. + 0.5
C
40    CONTINUE
C
      WRITE (2,900) CNTNAM(I), IZ
C
```

```
C   INCREMENT GROUP TOTALS
          DO 45 NZ=1,10
          IZT(NZ,IGRP) = IZT(NZ,IGRP) + IZ(NZ)
45        CONTINUE
          NCT(IGRP) = NCT(IGRP) +1
C
50        CONTINUE
C***
C
60        CONTINUE
C*
C
C      PRINT SUMMARY AVERAGES
C
          DO 80 J=1,6
          NCT(0) = NCT(0) + NCT(J)
C
          DO 70 I=1,10
          IZT(I,0) = IZT(I,0) + IZT(I,J)
70        CONTINUE
80        CONTINUE
C
          NCT(8) = NCT(0) + NCT(7)
          DO 90 I=1,10
          IZT(I,8) = IZT(I,0) + IZT(I,7)
90        CONTINUE
C
          WRITE (2,*)CHAR(12)
          WRITE (2,1000) CMDNAM
          WRITE (2,200)
          WRITE (2,300)
          WRITE (2,400)
          WRITE (2,500)
          WRITE (2,400)
          WRITE (2,600)
          WRITE (2,700)
          WRITE (2,800)
          WRITE (2,200)
C
          DO 130 IGRP=0,8
C
          DO 816 K=1,10
816       IZ(K)=0
C
          B = NCT(IGRP)
          IF (B.EQ.0.) GO TO 120
C
          DO 110 I=1,10
          T = IZT(I,IGRP)
          IZ(I) = (T/B) + 0.5
          IF (I.EQ.8) IZ(I) = (T/B) - 0.5
110       CONTINUE
C
120       WRITE (2,1100) GRPNAM(IGRP),IZ
130       CONTINUE
C
C
          RETURN
C
```

```
100     FORMAT (' SUMMARY: ',A24)
200     FORMAT (1X,132('-'))
300     FORMAT (1X,'REGION WHERE',6X,'TOTAL',9X,'SPILLOVER',1X,
     X         'BENEFITS DUE',19X,
     X         'DISTRIBUTIVE EFFECTS (% OF TOTAL BENEFITS)')
400     FORMAT (56X,76('-'))
500     FORMAT (1X,'RESEARCH IS',7X,'INTERNATIONAL',1X,'BENEFITS',
     X          2X,'TO ACIAR',18X,'CONSUMERS',30X,'PRODUCERS')
600     FORMAT (1X,'UNDERTAKEN',8X,'BENEFITS',16X,'INCREMENT',5X,
     X          'DEVELOPING  DEVELOPED    TOTAL',10X,'DEVELOPING',
     X          7X,'DEVELOPED    TOTAL')
700     FORMAT (93X,17('-'))
800     FORMAT (19X,'($MUS)',8X,'($MUS)',4X,'($MUS)',44X,
     X          'GAINERS    LOSERS')
850     FORMAT (/1X,A16)
900     FORMAT (2X,A12,5X,I6,8X,I6,3X,I6,8X,I6,5X,I7,4X,
     X          I7,5X,I7,5X,I6,4X,I7,4X,I7)
1000    FORMAT (' SUMMARY AVERAGES: ',A24)
1100    FORMAT (/1X,A16,I8,8X,I6,3X,I6,8X,I6,5X,I7,4X,
     X          I7,5X,I7,5X,I6,4X,I7,4X,I7)
        END
```

Appendix D

Detailed Information Generated by the Analysis: An Example for Groundnuts

GROUNDNUTS : ASSESSMENT OF MULTI-COUNTRY RESEARCH
======================= PRESENT VALUE OF GROSS BENEFITS AND DISTRIBUTION OF GROSS BENEFITS ($US M)

REGION WHERE RESEARCH IS UNDERTAKEN

	AFRICAWT1	AFRICAWT2	AFRICAWDT1	AFRICAWDT2	AFRICAWDT3	AFRICASAT1	AFRICASAT2	AFRICASAT3	AFRICATM1
TOTAL INTERNATL. BENEFITS	8.5	7.3	13.4	20.8	27.7	16.7	68.6	47.0	31.7
SPILLOVER EFFECTS	7.0	6.9	12.2	18.9	24.6	16.0	48.9	39.2	31.1
TOTAL BENEFITS DUE TO ACIAR INCREMENT	1.4	1.0	1.5	3.5	5.4	2.1	12.9	9.0	4.4
NATIONAL BENEFITS PRODUCTION REGIONS									
AFRICAWT1									
- CONSUMERS	0.6	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.1
- PRODUCERS	0.9	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.1
AFRICAWT2									
- CONSUMERS	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.1
- PRODUCERS	0.1	0.4	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
AFRICAWDT1									
- CONSUMERS	0.1	0.0	0.1	0.1	0.2	0.1	0.4	0.3	0.2
- PRODUCERS	0.2	0.2	1.1	0.2	0.0	0.0	-0.2	-0.2	0.0
AFRICAWDT2									
- CONSUMERS	0.0	0.0	0.1	0.2	0.1	0.1	0.3	0.2	0.2
- PRODUCERS	0.1	0.2	0.3	1.7	0.4	0.1	0.1	-0.1	0.2
AFRICAWDT3									
- CONSUMERS	0.1	0.1	0.1	0.2	0.4	0.1	0.5	0.3	0.2
- PRODUCERS	0.2	0.1	0.2	0.6	2.8	0.4	0.2	-0.1	0.3
AFRICASAT1									
- CONSUMERS	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.1
- PRODUCERS	0.0	0.0	0.0	0.0	0.1	0.6	-0.1	-0.1	0.0
AFRICASAT2									
- CONSUMERS	0.2	0.2	0.4	0.6	0.8	0.5	3.1	1.3	1.0
- PRODUCERS	0.2	0.1	0.9	2.2	2.7	2.5	16.6	3.8	3.4
AFRICASAT3									
- CONSUMERS	0.1	0.1	0.2	0.3	0.5	0.3	1.0	1.3	0.5
- PRODUCERS	-0.2	-0.2	-0.1	0.0	0.1	0.6	1.2	6.5	0.2
AFRICATM1									
- CONSUMERS	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1
- PRODUCERS	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.5
AFRICATM2									
- CONSUMERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AFRICATM3									
- CONSUMERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AFRICATM4									
- CONSUMERS	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
LATAMWDT3									
- CONSUMERS	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1
- PRODUCERS	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1
LATAMTM2									
- CONSUMERS	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LATAMTM3									
- CONSUMERS	0.0	0.0	0.0	0.1	0.1	0.0	0.2	0.1	0.1
- PRODUCERS	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.1
LATAMT/ST									
- CONSUMERS	0.1	0.1	0.1	0.2	0.2	0.2	0.6	0.4	0.3
- PRODUCERS	0.7	0.3	0.4	0.3	0.3	0.2	-0.4	-0.1	0.5
LATAMSTT									
- CONSUMERS	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1
- PRODUCERS	-0.1	-0.1	-0.1	0.0	-0.1	-0.1	-0.2	0.3	0.1
ASIAWT1									
- CONSUMERS	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASIAWT2									
- CONSUMERS	0.1	0.1	0.2	0.4	0.5	0.3	1.1	0.8	0.6
- PRODUCERS	1.4	1.3	1.2	0.6	0.5	-0.1	-0.8	-0.8	-0.1
ASIAWDT2									
- CONSUMERS	0.0	0.0	0.1	0.1	0.1	0.1	0.3	0.2	0.1
- PRODUCERS	0.1	0.2	0.0	0.4	0.5	0.2	0.2	-0.1	0.2
ASIAWDT3									
- CONSUMERS	0.1	0.1	0.1	0.2	0.2	0.1	0.5	0.4	0.3
- PRODUCERS	0.1	0.1	0.2	0.4	0.4	0.2	0.1	-0.1	0.3
ASIASAT2									
- CONSUMERS	1.0	0.9	1.6	2.5	3.3	2.1	7.6	5.5	3.9
- PRODUCERS	0.9	1.9	3.7	4.5	6.4	4.2	20.7	13.2	9.7
ASIAWST									
- CONSUMERS	0.6	0.5	0.9	1.5	1.9	1.2	4.5	3.2	2.3
- PRODUCERS	0.3	0.1	0.8	2.0	1.6	1.9	6.4	7.4	3.3
WANAMED2									
- CONSUMERS	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1
- PRODUCERS	0.0	0.0	0.0	0.0	-0.1	0.0	-0.1	0.0	0.0
WANAMED3									
- CONSUMERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NAMERICA									
- CONSUMERS	0.2	0.2	0.4	0.6	0.8	0.5	1.8	1.3	0.9
- PRODUCERS	-0.3	-0.2	-0.4	-0.7	0.8	-0.6	-1.0	-0.6	-1.1
DEVAS									
- CONSUMERS	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.1
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
DEVOC									
- CONSUMERS	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DEVAFR									
- CONSUMERS	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.1
- PRODUCERS	-0.1	0.0	-0.1	-0.1	0.1	-0.1	0.1	0.0	1.0

OTHER PRODUCTION AND CONSUMPTION REGIONS

ODINS									
- CONSUMERS	0.0	0.0	0.1	0.1	0.1	0.1	0.3	0.2	0.2
- PRODUCERS	-0.1	-0.1	-0.1	-0.2	-0.3	-0.2	-0.6	-0.4	-0.3
ODINC									
- CONSUMERS	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.1	0.1
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ODEVS									
- CONSUMERS	0.1	0.0	0.1	0.1	0.2	0.1	0.4	0.3	0.2
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ODEVC									
- CONSUMERS	0.2	0.2	0.4	0.6	0.8	0.5	1.9	1.4	1.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

GROUNDNUTS : ASSESSMENT OF MULTI-COUNTRY RESEARCH
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REGION WHERE RESEARCH IS UNDERTAKEN

	AFRICATM2	AFRICATM3	AFRICATM4	LATAMWDT3	LATAMTM2	LATAMTM3	LATAMT/ST	LATAMSTT	ASIAWT1
TOTAL INTERNATL. BENEFITS	24.5	14.0	4.9	29.3	25.9	31.0	33.4	28.0	3.5
SPILLOVER EFFECTS	24.4	13.8	4.5	28.9	25.6	30.2	27.8	23.9	3.3
TOTAL BENEFITS DUE TO ACIAR INCREMENT	4.1	1.7	0.6	2.9	5.2	3.9	5.2	2.2	0.3
NATIONAL BENEFITS PRODUCTION REGIONS									
AFRICAWT1									
- CONSUMERS	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2
- PRODUCERS	0.1	0.0	0.0	0.1	0.1	0.0	0.2	0.0	0.2
AFRICAWT2									
- CONSUMERS	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.1	0.1
AFRICAWDT1									
- CONSUMERS	0.2	0.1	0.0	0.2	0.2	0.2	0.2	0.2	0.0
- PRODUCERS	0.0	-0.1	0.1	-0.1	0.0	-0.1	0.0	-0.2	0.2
AFRICAWDT2									
- CONSUMERS	0.1	0.1	0.0	0.1	0.1	0.1	0.2	0.1	0.0
- PRODUCERS	0.2	0.0	0.2	0.2	0.1	0.1	0.1	-0.1	0.1
AFRICAWDT3									
- CONSUMERS	0.2	0.1	0.0	0.2	0.2	0.2	0.2	0.2	0.0
- PRODUCERS	0.3	0.2	0.2	0.4	0.3	0.1	0.1	-0.1	0.1
AFRICASAT1									
- CONSUMERS	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	0.0
AFRICASAT2									
- CONSUMERS	0.7	0.4	0.1	0.9	0.8	0.9	0.9	0.8	0.1
- PRODUCERS	3.2	1.5	0.2	2.4	2.0	2.6	1.2	0.3	-0.1
AFRICASAT3									
- CONSUMERS	0.4	0.2	0.1	0.5	0.4	0.5	0.5	0.5	0.1
- PRODUCERS	0.2	0.3	-0.1	-0.1	0.2	0.3	-0.4	0.4	-0.1
AFRICATM1									
- CONSUMERS	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0
- PRODUCERS	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0
AFRICATM2									
- CONSUMERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
- PRODUCERS	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AFRICATM3									
- CONSUMERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
- PRODUCERS	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AFRICATM4									
- CONSUMERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
- PRODUCERS	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
LATAMWDT3									
- CONSUMERS	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0
- PRODUCERS	0.1	0.0	0.0	0.3	0.0	0.0	0.1	0.0	0.0
LATAMTM2									
- CONSUMERS	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0

LATAMTM3									
- CONSUMERS	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0
- PRODUCERS	0.1	0.1	0.0	0.0	0.1	0.6	0.1	0.1	0.0
LATAMT/ST									
- CONSUMERS	0.2	0.1	0.0	0.3	0.2	0.3	0.5	0.2	0.0
- PRODUCERS	0.4	0.0	0.6	0.4	0.3	0.6	5.1	0.8	0.4
LATAMSTT									
- CONSUMERS	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.0
- PRODUCERS	0.4	0.2	0.0	0.0	0.2	0.5	0.8	4.1	0.0
ASIAWT1									
- CONSUMERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
ASIAWT2									
- CONSUMERS	0.5	0.3	0.1	0.6	0.5	0.6	0.6	0.5	0.1
- PRODUCERS	0.0	-0.1	0.2	0.1	0.3	-0.1	0.4	-0.5	1.5
ASIAWDT2									
- CONSUMERS	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0
- PRODUCERS	0.2	0.0	0.1	0.2	0.3	0.1	0.1	-0.1	0.2
ASIAWDT3									
- CONSUMERS	0.2	0.1	0.0	0.3	0.2	0.3	0.3	0.2	0.0
- PRODUCERS	0.3	0.0	0.1	0.2	0.2	0.1	0.2	-0.1	0.2
ASIASAT2									
- CONSUMERS	3.1	1.7	0.6	3.7	3.2	3.8	3.9	3.3	0.4
- PRODUCERS	8.7	4.5	-0.6	10.1	8.6	8.5	8.2	4.3	-0.4
ASIAWST									
- CONSUMERS	1.8	1.0	0.3	2.1	1.9	2.3	2.3	1.9	0.2
- PRODUCERS	0.5	2.1	0.4	2.7	2.0	2.6	0.6	4.4	-0.3
WANAMED2									
- CONSUMERS	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0
- PRODUCERS	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0
WANAMED3									
- CONSUMERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NAMERICA									
- CONSUMERS	0.7	0.4	0.1	0.9	0.8	0.9	0.9	0.8	0.1
- PRODUCERS	0.0	-0.5	0.9	0.4	0.5	2.4	3.2	3.6	-0.1
DEVAS									
- CONSUMERS	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0
- PRODUCERS	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.2	0.0
DEVOC									
- CONSUMERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
DEVAFR									
- CONSUMERS	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0
- PRODUCERS	-0.2	-0.1	0.1	0.0	-0.1	0.1	0.5	0.2	0.0

OTHER PRODUCTION AND CONSUMPTION REGIONS

ODINS									
- CONSUMERS	0.1	0.1	0.0	0.2	0.1	0.2	0.2	0.1	0.0
- PRODUCERS	-0.2	-0.1	0.0	-0.3	-0.3	-0.3	-0.3	-0.3	0.0
ODINC									
- CONSUMERS	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ODEVS									
- CONSUMERS	0.2	0.1	0.0	0.2	0.2	0.2	0.2	0.2	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ODEVC									
- CONSUMERS	0.8	0.4	0.1	0.9	0.8	0.9	1.0	0.8	0.1
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

GROUNDNUTS : ASSESSMENT OF MULTI-COUNTRY RESEARCH

PRESENT VALUE OF GROSS BENEFITS AND DISTRIBUTION OF GROSS BENEFITS ($US M)

	REGION WHERE RESEARCH IS UNDERTAKEN								
	ASIAWT2	ASIAWDT2	ASIAWDT3	ASIASAT2	ASIAWST	WANAMED2	WANAMED3	NAMERICA	DEVAS
TOTAL INTERNATL. BENEFITS	21.5	36.1	36.1	105.4	74.6	16.3	12.8	46.8	23.8
SPILLOVER EFFECTS	12.8	34.1	33.5	29.2	36.4	15.4	12.4	23.7	22.5
TOTAL BENEFITS DUE TO ACIAR INCREMENT	4.6	6.0	6.6	13.2	9.9	1.5	1.2	0.0	0.0
NATIONAL BENEFITS PRODUCTION REGIONS									
AFRICAWT1									
- CONSUMERS	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
- PRODUCERS	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
AFRICAWT2									
- CONSUMERS	0.1	0.1	0.1	0.3	0.2	0.1	0.0	0.1	0.1
- PRODUCERS	0.1	0.0	-0.1	-0.2	-0.1	0.0	0.0	-0.1	-0.1
AFRICAWDT1									
- CONSUMERS	0.1	0.2	0.2	0.5	0.4	0.1	0.1	0.3	0.2
- PRODUCERS	0.2	0.2	0.0	-0.3	-0.3	-0.1	-0.1	-0.2	-0.1
AFRICAWDT2									
- CONSUMERS	0.1	0.2	0.2	0.4	0.3	0.1	0.1	0.2	0.1
- PRODUCERS	0.2	0.3	0.2	-0.2	-0.1	-0.1	-0.1	-0.2	-0.1
AFRICAWDT3									
- CONSUMERS	0.1	0.3	0.3	0.6	0.5	0.1	0.1	0.3	0.2
- PRODUCERS	0.3	0.6	0.4	-0.1	-0.2	-0.1	-0.1	-0.1	-0.1
AFRICASAT1									
- CONSUMERS	0.1	0.1	0.1	0.3	0.2	0.1	0.0	0.1	0.1
- PRODUCERS	-0.1	0.0	0.0	-0.3	-0.2	-0.1	-0.1	-0.2	-0.1
AFRICASAT2									
- CONSUMERS	0.5	1.1	1.1	2.2	1.8	0.5	0.4	1.1	0.7
- PRODUCERS	0.1	2.3	2.0	4.4	3.0	0.5	0.6	-0.6	-0.1
AFRICASAT3									
- CONSUMERS	0.3	0.6	0.6	1.3	1.0	0.3	0.2	0.6	0.4
- PRODUCERS	-0.4	-0.3	-0.1	0.5	1.0	0.5	0.6	-0.5	-0.5
AFRICATM1									
- CONSUMERS	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.0
- PRODUCERS	0.0	0.1	0.1	0.0	0.0	0.0	0.0	-0.1	0.0
AFRICATM2									
- CONSUMERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
- PRODUCERS	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0
AFRICATM3									
- CONSUMERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AFRICATM4									
- CONSUMERS	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.0
- PRODUCERS	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0
LATAMWDT3									
- CONSUMERS	0.0	0.1	0.1	0.2	0.1	0.0	0.0	0.1	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LATAMTM2									
- CONSUMERS	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LATAMTM3									
- CONSUMERS	0.0	0.1	0.1	0.2	0.1	0.0	0.0	0.1	0.1
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LATAMT/ST									
- CONSUMERS	0.2	0.3	0.3	0.7	0.5	0.1	0.1	0.3	0.2
- PRODUCERS	0.6	0.5	0.3	-0.3	-0.2	-0.2	-0.1	0.5	0.2
LATAMSTT									
- CONSUMERS	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.0
- PRODUCERS	-0.2	-0.2	-0.1	-0.1	0.4	0.3	0.3	0.6	0.6
ASIAWT1									
- CONSUMERS	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASIAWT2									
- CONSUMERS	0.6	0.7	0.7	1.4	1.1	0.3	0.2	0.7	0.4
- PRODUCERS	8.2	1.3	0.5	-0.7	-0.5	-0.3	-0.2	-0.7	-0.4
ASIAWDT2									
- CONSUMERS	0.1	0.3	0.2	0.3	0.3	0.1	0.1	0.2	0.1
- PRODUCERS	0.5	1.7	0.3	0.2	0.1	-0.1	-0.1	-0.1	-0.1
ASIAWDT3									
- CONSUMERS	0.2	0.3	0.5	0.6	0.5	0.1	0.1	0.3	0.2
- PRODUCERS	0.3	0.4	2.1	0.2	0.1	-0.1	-0.1	-0.2	-0.2
ASIASAT2									
- CONSUMERS	2.2	4.4	4.4	15.7	7.4	2.0	1.6	4.7	2.9
- PRODUCERS	3.2	12.1	12.9	60.4	10.1	2.3	0.5	7.0	5.3
ASIAWST									
- CONSUMERS	1.3	2.6	2.6	5.5	7.3	1.2	0.9	2.8	1.7
- PRODUCERS	1.4	3.2	3.8	3.7	30.9	4.2	5.6	4.5	6.5
WANAMED2									
- CONSUMERS	0.0	0.1	0.1	0.2	0.1	0.1	0.0	0.1	0.1
- PRODUCERS	0.0	-0.1	-0.1	-0.1	0.0	0.8	0.2	0.0	0.1
WANAMED3									
- CONSUMERS	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
- PRODUCERS	0.0	0.0	0.0	-0.1	0.0	0.1	0.3	0.0	0.0
NAMERICA									
- CONSUMERS	0.5	1.1	1.1	2.2	1.8	0.5	0.4	1.9	0.7
- PRODUCERS	-0.6	-0.4	-0.4	1.9	3.2	1.7	0.3	21.2	2.1
DEVAS									
- CONSUMERS	0.1	0.1	0.1	0.3	0.2	0.1	0.0	0.1	0.1
- PRODUCERS	0.0	-0.1	-0.1	0.0	0.2	0.2	0.2	0.1	1.1
DEVOC									
- CONSUMERS	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.0
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1
DEVAFR									
- CONSUMERS	0.1	0.1	0.1	0.3	0.2	0.1	0.0	0.1	0.1
- PRODUCERS	-0.1	-0.1	-0.1	-0.1	0.3	0.4	0.0	0.1	0.3

OTHER PRODUCTION AND CONSUMPTION REGIONS

ODINS									
- CONSUMERS	0.1	0.2	0.2	0.4	0.3	0.1	0.1	0.2	0.1
- PRODUCERS	-0.2	-0.4	-0.4	-0.7	-0.6	-0.2	-0.1	-0.4	-0.2
ODINC									
- CONSUMERS	0.1	0.1	0.1	0.2	0.2	0.1	0.0	0.1	0.1
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ODEVS									
- CONSUMERS	0.1	0.2	0.2	0.5	0.4	0.1	0.1	0.3	0.2
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ODEVC									
- CONSUMERS	0.5	1.1	1.1	2.3	1.8	0.5	0.4	1.2	0.7
- PRODUCERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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