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Weighing the Risks of Change:

Technology, Institutions and Project Implementation

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I. Introduction and Overview

One of the most important but subtle features of life in a developed economy such as the United States is that we can count on things when we need them. If we need to go somewhere, a transportation system exists to take us there. If we need to buy something, it is available, somewhere, at a price. If we are wronged, a legal system exists to allow redress of grievances. If we need to build something, the tools are available, or someone with the tools will build it for us, for a price. The evolution of modern technology and institutions has taken much of the uncertainty out of life. What was formerly variable is fixed by technologies or institutions.

Perhaps the major area of our economy where this is least true is farming. Farming remains subject to a variety of uncertainties of weather, rainfall, climate, and price fluctuations which, despite increasing technological sophistication, make it one of the riskiest businesses in a developed economy. The random, essentially uncontrollable, forces to which it is subject have not entirely relented to technology or institutions bringing them under control. Still, even risks in farming have been reduced by many technological and institutional innovations, especially in the highly productive U.S. farm sector. Fertilizers, pesticides, high-yielding seeds, futures markets, cooperatives, and other inventions make farming far less risky than in the past.

In a developing economy, in contrast, the characteristic feature of life most striking to those who first encounter it is that things are unavailable when they are needed. Transportation systems are unreliable or non-existent. Commodities of all types, even if imported, are often simply unavailable. The

legal system is rudimentary and often apparently unfair or even corrupt. If something must be built, the tools may not exist to build it, or the skills are not for hire by those who can. What was certain at home due to the existence of technology or institutions is now variable. A classic response by visitors from abroad is to create enclaves of modernity, the main feature of which is that the amenities of home can be counted on.

If the uncertainty of life in a developing economy is apparent even to visitors to its most modern sectors - a capital city or AID mission - this uncertainty is multiplied many fold in the major productive activity of farming. Just as in developed economies, farmers in the Third World face vagaries of weather, rainfall, climate and price fluctuations. In many areas, these uncertainties are even worse than in the temperate growing regions of North America. Drought, monsoons, temperature extremes, mariginal soils, and unexpected price fluctuations are typical features of many developing economies. Added to these natural uncertainties are the full range of problems of dependability. Transportation systems do not facilitate produce to go to market. Seeds, fertilizers, and other inputs often are unavailable when needed. Contracts including claims on basic resources such as land and water are insecure. In short, all of the uncertainties which existence can bestow are the lot of the traditional farmer. His is a life shot through with risk--often threatening the life of his family and himself.

For those used to the comparative stability and certainty of life in a developed economy--even those who have grown up with agriculture--these risks

may be difficult to appreciate. When technologies are proposed which promise higher returns, the risks which may attend the adoption of these techniques to the farmer are often overlooked. When new institutions are introduced, such as credit or marketing boards, the general environment of institutional uncertainty in which traditional farmers operate often makes these changes seem highly risky compared with established, albeit unsatisfactory, institutional arrangements. These risks are an important aspect of project planning which deserve more careful analysis.

The following paper is an analytical essay in project planning. It seeks to clarify some basic issues in project implementation which are raised by two streams of research. The first is the wide-range of theory and empirical evidence concerned with risk and risk-aversion by farmers. This research, widely acknowledged as important to the realization of project goals, has not been systematically linked to problems of project implementation. The second research stream is the role of technology, institutions and change in economic development, represented by Hayami and Ruttan's Agricultural Development: An International Perspective (1971) and Binswanger and Ruttan's Induced Innovation: Technology, Institutions and Development (1978). This work has emphasized the similarity and interdependence of technological and institutional change, and has suggested the wisdom of examining them in parallel.

This study brings these streams of research to bear on some problems of project implementation. It is often forgotten that the basic decisions determining the success or failure of development assistance are not those of

the project planner, but the project recipient: to adopt or not to adopt a new technology; to build or not to build a new institution. These decisions involve added risks in an already risky environment associated with new and often strange methods and techniques. By focusing directly on risks to the farmer and farm household, it is not intended to abstract from the larger social, political, and environmental uncertainties which affect farmer decisions. Indeed, it is these very uncertainties which make household decision making in less developed countries so risky. However, only by identifying more precisely why these decisions are considered risky will it be possible to promote policies which will systematically lower these risks. By lowering the risks of change, more rapid advances in technology transfer and institutional development can be promoted. Risk reduction is not a special issue. It is the general purpose of successful implementation of projects.

A systematic examination of relationships between farmer risk aversion and the implementation of development assistance projects is therefore required. The following paper is divided into four major sections. The first examines the project as an agent of change in rural areas - the source of supply of new technologies and institutions. It links the project design concept to cost benefit analysis, and explores the difficulties of treating technology and institutions as fixed in relation to project goals. The second section examines the impact of the project in terms of the risks it may pose to farmers using traditional technologies and institutions and provides a theoretical basis for decomposing such risks into their separate elements. The third section considers how these risks may act to constrain the

achievement of project goals, and how such constraints may affect the capacity to transfer technologies and institutions. The analysis of the second section is then applied to indicate the types of efforts necessary to lower risks perceived by farmers in the implementation of the project. These efforts may involve either raising expected outputs of project components or lowering variance surrounding the impacts of these components. In addition, technologies and institutions which share many of the characteristics of existing ones will lower overall risks to farmers facilitating the process of implementation. The fourth section concludes with an agenda for further policy research, based on ten questions relevant to project implementation. By focusing directly on these questions, projects can attend to the specific factors most likely to accelerate the process of technology transfer and institutional change by overcoming risks attached to these changes by farmers.

The general implications of this research for project implementation may be summarized as follows.

1. In the project setting, technology and institutions are clearly variables. This implies that technological and institutional change are part of project implementation. Technological and institutional change raise risks to farmers. Risks are defined as the likelihood or probability that outputs and incomes will fall below some threshold level. The farmer adopting a new seed or taking part in institutional reform wants to know how likely it is that he or she will end up better off for the change. If "better" is defined by reference to output and incomes with existing technology and institutions, then this baseline is the standard or threshold by which the risks of change are judged.

2. Project implementors must therefore identify the specific technological and the institutional changes necessary to achieve project benefits. Traditional economics has not been terribly helpful because both technology and institutions are taken as given. If we propose to introduce a new HYV of maize or a new marketing structure or set of credit institutions, such a static approach will not suffice. The very definition of the project involves dynamic changes in these variables.

3. After the changes have been identified, it must be recognized that new technologies and institutions will create major questions in the minds of the recipients of project aid. These questions may be expressed as risks associated with the adoption of a new maize variety, for example, or with participation in a new marketing or credit institution. This is consistent with a variety of empirical studies which show that the risks of technological and institutional change are often major constraints on the achievement of project goals. Here AID's traditional tools of analysis -- such as the log-frame -- are not of much use since they fail to focus specifically on the risks perceived by farmers.

4. Project implementors must then identify whether these risks pose constraints to the achievement of project goals. How much change can farmers tolerate before the risks of a new way of doing things becomes too high, and they fail to adopt them? To project recipients, the question is more straightforward: What is the likelihood (or probability) that a new maize variety or a new marketing institution will lead to levels of output and income <u>lower</u> than what they have already? If the perceived or actual likelihood, i.e., the risk, <u>is</u> a constraint on the achievement of project goals, then the project cannot move forward.

5. In project implementation, there are three major methods of risk reduction. The first is to raise the expected returns resulting from technological and institutional innovation. The second is to reduce the variability surrounding these returns, raising confidence in the methods to be transferred. The third is to introduce technology and institutions both general characteristics similar to existing methods. To take the example of a HYV of maize and new marketing scheme, farmers' willingness to plant the seed and participate in marketing is a result of overcoming three types of problems. First is the expected difference between average levels of output grown and marketed under the project compared with the status quo. The greater this difference, the less the perceived risks of adopting the new technology and institutions. Second, substantial gains of this "high-payoff" type will be traded for smaller gains, <u>if</u> these gains are assured. Thus, risks also fall if the variability of the seed or marketing institutions performance is low. Third, either of these features may be traded off if the proposed seed or marketing institution is highly familiar to the farmer, and he reacts predictably to typical influences in the environment. If risks constrain the achievement of project goals, then credit, factor prices, stable government policies, and effective extension efforts may all be used to reduce risk by increasing expected returns, reducing variability, and identifying methods which are similar to existing techniques or institutions.

6. More generally, lowering risks requires implementation based on accurate and complete information designed to provide answers to farmers' questions, which arise by attempts to promote accelerated rates of change. By

providing improved information, for example, successful on-farm research and extension systems together with efficient systems of market prices can rapidly accelerate project development. Current emphasis on decentralized, bottom-up institutions is also explicable in these terms, since they are often more informationally efficient compared with unwieldly, top-down authority. Furthermore, decentralized approaches to project implementation create grass-roots demands for technical and institutional change. This suggests a need to reexamine the role of extension and communication with farmers generally. If extension and communication efforts can reduce farmers' risks, more rapid transfers of technology and acceptance of new institutions may result, increasing the benefits of project assistance.

In sum, the implementation of the project may be understood as a three step learning process. This paper provides an analytical foundation for such an evolutionary or learning approach to project implementation. First, the technical and institutional risks perceived by farmers must be identified. Second, these risk constraints can then be addressed as questions of <u>returns</u>, <u>variability</u>, and <u>familiarity</u> of technologies and institutions. Finally, policies can be implemented which raise returns, reduce variability, and increase familiarity with the new technologies and institutions. By identifying risks as constraints to the implementation of projects, greater emphasis can be given to policies which slowly remove these constraints over time. Policies which systematically reduce risk will stimulate incentives to adopt both new technologies and new institutions beyond the life of the project itself.

II. The Project and the Supply of Change

The development project is a major instrument of technological and institutional change in the developing world. Its design and implementation, as well as the criteria used to appraise its performance, reflect the basic goals and purposes of the donor agencies. Over time, different approaches to development due to changing needs and theories, have been reflected in the way projects are designed and implemented. These changing approaches mirror ideas of the development process itself.

Early capital investment and infrastructure projects were described by reference to basic accounting principles borrowed from banking and finance. In the late 1950's, these principles were generalized by economists involved in water resources planning and other public works to yield more refined project plans.[1] Tinbergen first proposed applying to development projects what are now well established conventions in benefit-cost analysis,[2] arguing that by linking benefits and costs of individual projects to an overall macroeconomic program, their contribution to capital formation and growth in national product could be estimated and compared.[3] Prompted by a growing body of economic theory and shifts from a macroeconomic to microeconomic emphasis, more refined methods were subsequently developed and adopted by the development agencies, resulting in manuals which explored the detailed issues of project planning.[4]

At the core, these methods are based on theoretical welfare economics, making the principles underlying all projects analysis equivalent, although the emphasis of each project varies. The methods all include:

1. a definition of the affected project area and the accounting prices to be used in the calculation of costs and benefits;

2. a description of the circumstances which would prevail in the absence of the project as a baseline for calculation of net benefits of the project;
3. identification of the economic units (individuals, firms, government agencies) affected by the project and statements concerning their relative importance;
4. calculation of direct and indirect costs and benefits of the project in terms of changes in the incomes and expenditures of the affected economic units;
5. analysis of distributive impacts and secondary effects involving unemployed factors (labor, raw materials, and capital);
6. application of one or several selection criteria such as net discounted benefits, internal rate of return; or benefit cost ratios for comparison of project alternatives.[5]

Underlying the methods is a basic welfare emphasis on the supply of and demand for income streams associated with the project or its individual components. Application of these methods results in a documentary basis for project planning and implementation.[6]

The underlying purpose of the project is thus to be a supplier of change. For example, if a project involves introduction of high-yielding maize which is expected to raise output and incomes, failure to implement the maize component results in (opportunity) losses of (these) income streams to producers. The project, by providing the high-yielding seed and necessary inputs, reduces the supply price of these inputs, lowering marginal costs and shifting the supply

curve for maize. The result of successful implementation is increased output and incomes to producers. On the demand side, components such as marketing boards can increase the quantity of maize purchased with corresponding effects on the incomes of producers.

The welfare basis of such shifts in supply and demand is the increase in consumer and producer surplus resulting from the project. The sum of all demand and supply side impacts, discounted over the relevant time period, describes net benefits.[7] Because these cost-benefit criteria are descended from the common lineage of theoretical welfare economics, they assume that conditions hold under which supply and demand shifts are reflected in prices, which are, in turn, accurate indicators of net benefits. These "efficiency" conditions also allow prices to forecast future supply and demand relationships between factors of production, output, consumption, and resulting income streams.[8]

However, even early applications of these methods to development projects recognized that circumstances in less developed economies did not enable market prices to signal efficient economic choices. Inflation, currency overvaluation, underemployment, imperfect capitol markets, and other resource constraints created distortions in price signals. In many cases the "market" for a newly introduced commodity simply did not exist. As a consequence, social accounting or "shadow" prices were introduced which, by correcting market distortions, explicitly acknowledged constraints to efficient economic allocation. From an analytical point of view, identifying these constraints is the first step in project planning, since the constraints reflect basic assumptions about scarce resources.

The outcome of any project planning exercise is therefore a function of the recognized constraints to efficient economic allocation. As Lal, emphasizing the basic similarity of all such methods, notes: "any substantive differences among the alternative procedures are in large part dependent upon the differing assumptions about the relevant aspects of the economic environment in which the investment decision is made."[9] Thus, identifying the constraints which affect realization of project benefits is the key to project planning. A failure to identify these constraints with some accuracy can bias the entire process of planning and implementation, whether or not the constraints are expressed in terms of formal cost-benefit criteria.[10]

One area in which documented field experience suggests the existence of a serious constraint is the risk associated with changes in both technology and institutions specifically introduced by the project. Despite wide interest in the impact of risk on decision making, no existing systems of project analysis systematically treat it as an explicit constraint to project planning and implementation. This is due, in part, to the supposition carried down from welfare economics that efficient economic choices are conditioned on (1) a given state of technology; (2) a particular set of public and private institutions; and (3) the absence of uncertainty concerning changes in technology, institutions, and the prices which result. Yet if any or all of these conditions are not "given," economic choices and resulting levels of output and income streams will be affected. Project appraisal has not systematically confronted the fact that the major purpose of the project is often defined in terms of new technologies. Moreover, as project designs

increasingly emphasize institutional development, changes can occur only by changing existing institutional arrangements. Both new technologies and new institutions are the primary features of project assistance.

A full description of the economic environment must therefore attend to the impact of these changes on decisions by farmers. Recognized constraints should include not only scarce capital[11] or equitable distribution[12] but also the constraining effect of risks resulting from technical and institutional change. In this sense, the role of risk has not received treatment. Although integrated into some project appraisal methods as a way of setting upper and lower bounds on project impacts, technological or institutional changes have not been linked to the risks perceived by farmers themselves. Yet the lack of information and the resulting insecurity and uncertainty resulting from project assistance may create constraints which are as binding as more basic resources.[13]

In the discussion to follow, uncertainty is defined as the variance associated with a mean level of output which sets a range of confidence around this level. In contrast, risk is defined as the probability that output and incomes will be lower than some target level. Risk is the probability of not achieving a target level, such as the existing level of maize output. The risk resulting from new techniques and institutions is a function of but not identical with the variance surrounding the levels of output. A variety of other factors, to be discussed below, contribute to this risk.[14]

The basic argument is that if the risks of a new maize variety or marketing institution, for example, are perceived to be too high, proposed project changes may not be adopted or implemented. This possibility has important implications for project implementation. If risks constrain benefits, policies must be developed which reduce or compensate for risks before benefits can be achieved. Reducing risks to farmers suggests a special role for rural extention systems as well as private sector institutions profiting from rural change. As will be shown below, this role includes not only the demonstration of gains from new technologies and institutions by way of increases in average output and incomes, but also policies which reduce variability in output, as well as attention to the relationship between proposed changes and existing methods of production. At the operational level, both the private sector and public extension systems, by reducing the riskiness associated with new technology and institutions, can accelerate changes in output, incomes and welfare. But accelerated rates of change depend critically on policies which reduce the risks of this change to farmers.

The importance of giving attention to the risks associated with projects is reinforced by the interactive character of technology and institutions. The experience of the Green Revolution and mechanization programs in agriculture demonstrate that new technology often provides an impetus to change in rural institutions of land tenancy, access to employment, and other effects. Such changes, in turn, affect the technological environment, resulting in altered choices of technique and new streams of income. Because of interdependencies in technological and institutional change, as well as the constraints which they pose individually to implementation, projects should be

guided by an appropriate analytical framework which explicitly recognizes these risks in the assessment of needs, identification of possibilities, evolution of alternatives, and prediction of consequences. Such an inclusive framework, should produce fewer failed projects.[15]

III. Technological and Institutional Risk

In a traditional farming context successful diffusion of new technologies or institutional innovations is a function of the flow of information reaching the small farmer. For this reason, project design has evolved toward recognition of the necessity of direct contact with the farm unit as the basis of an effective rural development strategy. While development experts increasingly focus on the farm household as a basic decision unit, major questions remain over what policies should do to affect the decision calculus of the farmer. One important lesson, drawn from field experience, is that the role of the project is not only to increase knowledge of techniques and methods necessary to raise output, but also to instill confidence that these techniques or institutions will offer a high probability of success in comparison to traditional methods. This is partially a function of the technique being introduced itself, but also a question of the expected variability of the new technique compared with the old and the similarities and differences between traditional and new methods.

McInerney[16] has identified two aspects of expectations relevant to project implementation. First, lack of adequate knowledge about a technical package itself, such as the inputs necessary to successful adoption, can lead to outcomes different from expectations, creating an impression of unreliability. Especially among poor farmers, who are least able to bear risks, uncertainty concerning project methods can be a major impediment.

> "Uncertainty is always a characteristic of change, and when innovation involves shifting from an established self-contained and familiar

farming system, which has provided family subsistence (but little accumulation of reserves), to one involving the utilization of methods of which the target group has little experience, the information gap ... may appear to represent a chasm too risky to negotiate.[17]

Second, if the proposed changes in institutions accompanying the proposed technical package are too great, short-term project intervention will not be expected to achieve permanent institutional change. (The main impact of the project may instead be that) farmers are forced into a choice between existing institutional loyalties and new ones, which may raise serious questions over whether the changes are worth the risks. Small farmers who are asked to adapt to entirely new ways of doing things, such as a new marketing or credit system, for example, may find the implied risks too great to bear in comparison with traditional institutional arrangements.

These issues may be combined to yield a matrix describing the stylized facts of project implementation. The matrix below describes the relationship between new and existing technology (such as a traditional and HYV seed package) and new and existing institutions (such as an old and new marketing institution). The status quo is described in terms of the existing or "old" technology and institutions. Projects seeking only to implement new techniques of production (without attention to institutions) through the introduction of "technical packages" are described by the Northeast cell of the matrix. This implementation approach, popular during earlier phases of development experience, is pursued less often today in light of growing recognition of the role of institutions in implementation. An alternative

(harking to still earlier phases of development planning) involves project implementation focused entirely around "institution building", without attention to technical packages. This implementation approach is described in the Southwest cell of the matrix. However, an increasing emphasis is currently placed on combined efforts at institution building and technical assistance described in the Southeast corner of the matrix. Many projects in the AID and World Bank portfolio are now shifting to an implementation approach in which both institutions and technology must be altered, involving movements from Northwest to Southeast. It is the before and after change in technological and institutional characteristics resulting from this implementation process that thus determines net project benefits.[18]

Technology

Institutions	old = T	new = T*
old=I	IT	IT*
new=I*	I*T	I*T*

Where:

IT = status quo

IT* = introduction of "technical packages" only

I*T = "institution building," no technical packages

I*T* = institution building plus technical packages

Each of the technological and institutional characteristics I, T, I*, T* is associated with an expected level of output (Q) and income (Y). In other words, implementing new technology and institutions I*T* is intended to increase both output and incomes in comparison with the old institutions and technology IT. In a cost-benefit framework, we may say that by implementing T* and I*, project beneficiaries will reap the rewards (surplus) of increased production in the form of increased income.[19] Increased income due to increased maize production, resulting from implementation of a high-yielding maize technology, for example, may be expressed as a function of the difference $\Delta_{T*} = (T* - T)$ in technological characteristics of production before and after project implementation.

(1) $$Y[Q(\Delta_{T*}) = Q(T* - T)].$$

Similarly, the difference in income from maize production resulting from a new institutional arrangement - such as a new maize marketing board - may also be expressed as a function of a difference $\Delta_{I*} = (I*-I)$ in institutional characteristics before and after successful "institutional development."

(2) $$Y[Q(\Delta_{I*}) = Q(I* - I)].$$

The problem with traditional methods of project appraisal based on ordinary benefit-cost criteria is that they assume a transformation from existing technology and institutions to new ones without attention to the risks attending such a process. In other words, they assume that maximization of benefits resulting from changes in technology and institutions is unconstrained by these technological and institutional risks. If risks are ignored, it is possible in principle to calculate the expected income gains E(Y) resulting from technological and institutional change in terms of the

expected net benefits of the project, defined over project output (Q) in each time period i as below.

$$E[(Y(Q_i)] = E\left[\sum_{i=0}^{n} \frac{B(Qi) - C(Qi)}{\prod_{i} (1+r_i)}\right]$$

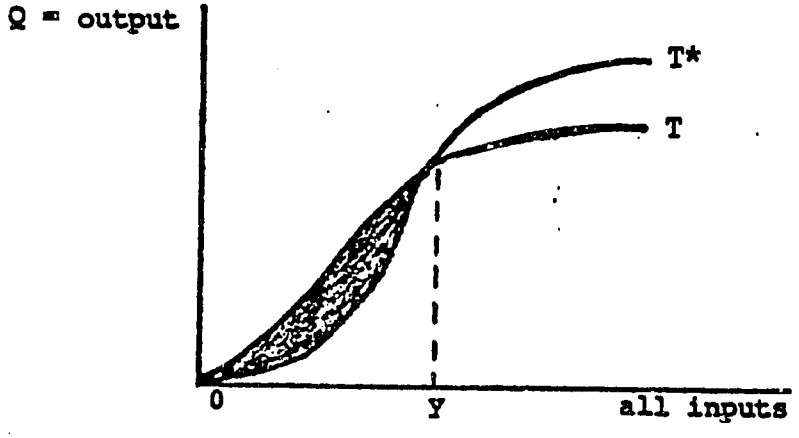
This simply says that the expected net benefits of increased project output are equal to the difference of benefits and costs of that output in each period i summed over some time horizon stretching from a beginning period 0 to a terminal period n, discounted in each period by $(1+r_i)$.

But where technology and institutions are not simply "given," it is important to describe the perceived risks resulting from changes in these variables as possible constraints on the maximization of net project benefits. To examine how both technological and institutional risk may affect small farm decisions, the example of a new, high-yielding maize variety (T*) and new marketing institution (I*) will be contrasted with traditional varieties (T) and marketing channels (I).

Technological Risk

For the farmer deciding whether to adopt the new maize variety technological risk may be expressed in terms of a basic question: What is the probability that the output and (at constant input and output prices) the income associated with the new maize variety will fall below that received from the existing variety? One way of thinking about this problem is to imagine two production functions, one associated with the existing maize

technology T and another associated with the new HYV technology T*, as in the figure below.



The shaded area represents the output losses possible with use of the new technology compared with the old. Note that these losses are particularly likely at low levels of inputs. As inputs rise, the newer technology increasingly dominates the old, until at y it is strictly dominant. If the shaded area represents the possible loss, then the probability of this loss is simply the probability that output due to the new technology T* will be less than that due to the old technology T. Existing production levels under technology T define the lower target level below which no farmer wants the new production level under technology T* to fall, especially since the T level, given available inputs, may already be at or near subsistence.

The risk that T* may end up less than T can be understood as a problem of the probability distribution of the two production functions. If both T* and T are distributed with a mean or expected level of output and with variance defined around that output measuring both objective and subjective

uncertainty, we can summarize these probability distributions in terms of these means and variances.

For the old technology:

$$E(T) = \mu_T \quad ; \quad V(T) = \sigma_T^2$$

For the new technology:

$$E(T^*) = \mu_{T^*} \quad ; \quad V(T^*) = \sigma_{T^*}^2$$

The probability that T* is less than T, defined as technological risk, may be expressed as R_{T^*}.

(4) $$R_{T^*} = \text{Prob. } (T^* < T) > 0$$

This simply says that if the probability that T* less than T is greater than zero, this implies that some risk is attached to the new technology. The more risk averse a farmer is, the lower the probability R_{T^*} he or she will tolerate and still adopt the new technology, although other more "entrepreneurial" farmers may be prepared to tolerate a higher level of risk. In any case, this risk may be expressed equivalently as

(5) $$R_{T^*} = \text{Prob. } [(T^* - T) < 0] > 0$$

As before, technological risk exists when $R_{T^*} > 0$. The term $(T^* - T)$ is simply the difference in output between the new and old technology, or technological change. As in equation (1), we define technological change in maize production as $\Delta_{T^*} = (T^* - T)$.

The probability that this change in output will be negative is thus a basic measure of risk. Since technological change is a function of both the new technology and the old, it is interesting to see how the expectations and variances of these technologies interact in terms of the change term,

$\Delta_{T*} = (T* - T)$. Since $(T* - T)$ is the convolution of $T*$ and $(-T)$, its own expectation and variance may be expressed as below.

(6) $$E(\Delta_{T*}) = \mu_{T*} - \mu_T$$

(7) $$V(\Delta_{T*}) = \sigma^2_{T*} + \sigma^2_T - 2\sigma_{T*T}$$

These results provide insight into the basic factors defining risk to the farmer and farm household. The expectation $E(\Delta_{T*})$ is simply the expected result of technological change on output and incomes. This is the difference between the average level of maize output expected of the new technology T* and the average level of maize output expected of the old technology T. The variance $V(\Delta T*)$ is defined as the sum of the variances in output and incomes of the new and old technologies respectively, minus two times their covariance. This is the uncertainty associated with technological change.

Together, these conditions suggest a variety of ways in which technological risks can be reduced. If the probability that T* is less than T creates unacceptable risks to farmers, one way to lower it is to raise the <u>expected</u> level of output associated with the new technology in relation to the old. Keeping variances constant, raising $E(T*) = \mu_{T*}$ will lower technological risk R_{T*}. This is fairly obvious, since the higher the expected yields resulting from the new maize variety, the lower the risk that they will fall below those of the old variety. Hence, raising the entire production function associated with T* will lower the probability that output due to T* will be less that output due to T.

However, an alternative way to lower risk is to lower the variance or uncertainty associated with technological change. Keeping other things constant, this can occur either by lowering σ^2_{T*}, the variance of output associated with the new maize, or lowering σ^2_T, the variance of output associated with the old. Since farmers planting traditional maize are generally much better informed about the range of output associated with their own varieties, and since traditional varieties are likely in any case to be ecologically better adapted, it will generally be the case that σ^2_{T*} σ^2_T However, a large measure of this difference may be due to subjective uncertainty associated with the new variety, which can be reduced through demonstration and education. These actions can lower the overall level of risk associated with the change.

A final possibility for risk reduction concerns the covariance term, σ_{T*T}. This term, if positive, will lower the overall level of risk. A positive correlation between old and new technology implies that systematic changes in output associated with the two technologies due to a variety of environmental impacts will vary on the low side or the high side together. In terms of the production functions for T* and T, we may say that variations in output are likely to be in the same direction - if production responds negatively to environmental impacts using technology T, it will also respond negatively using T*, and vice versa. Therefore, the magnitude of the σ_{T*T} term is a measure of the similarity or familiarity of the technologies' response to outside factors such as climate or rainfall. A negative value for σ_{T*T} would imply a negative association between the techniques, and a lack of similar response. This lack of similarity, as indicated in

equation (7), raises the uncertainty associated with technical change, and therefore the overall level of risk.

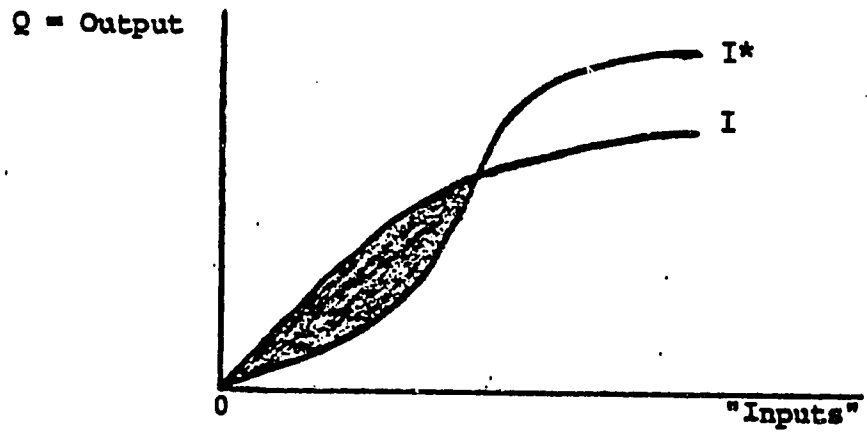
The five "moments" or arguments describing technological change (μ_{T*}, μ_T, σ^2_{T*}, σ^2_T, σ_{T*T}) offer a natural focus for policy formulation in project implementation. The terms μ_{T*} and μ_T, the expected levels of output respectively associated with the new and old techniques, are naturally relevant. Less obvious but no less important are σ^2_{T*}, σ^2_T and σ_{T*T}, describing the variance surrounding the new and old techniques and the covariance between these techniques. It is especially important to emphasize that risk reduction can occur by combining some increases in expected levels of output associated with the new technology with some reductions in variance or with increases in the similarity of response by the new and old techniques to environmental conditions.

The policy implications of these results will be explored in greater detail below. For the moment, the key point is that technological risk may be reduced by a variety of means. Each combination of intervention methods implies a different set of policy priorities and attendant costs. However, an appropriate combinations of these methods can achieve reduced risk. If risk is a binding constraint on the adoption of new techniques and the realization of project benefits, these findings have important implications for project implementation.

Institutional Risk

Institutional risk may be described in essentially the same terms as technological risk, although there are important differences in the process of risk reduction to be considered below. To pursue the example identified above, institutional risk is defined for the farmer or farm household contemplating participation in a new maize marketing scheme in terms of the following question: What is the likelihood that the output (and at constant input and output prices the income) associated with the new institutions will fall below that of the old? A more direct way of putting this is: What level of confidence exists in the proposed institutional alternative as a mechanism of change? If the new maize marketing institution is perceived as leading to new long-term outlets for sales, then this confidence will be high. But farmers with established marketing patterns may be extremely cautious about switching from sure but smaller markets to potentially larger markets which are untried and untested. Those "institutional entrepreneurs" who are willing may succeed, but many entrepreneurs fail before others succeed. These failures may have a dampening effect on the overall rate of institutional innovation. This reinforces the necessity of promoting confidence and bolstering the fortunes of early entrepreneurs.

Analogous to technology, institutional risk may be defined with respect to output. Again, it is possible to imagine this output as some function of the institutions in force at any time. If a new marketing board allows investments in maize to rise, we may think of the institutional arrangement as analogous in this sense to technology. For particular levels of political and social "inputs," these institutional arrangements will yield alternative levels of output as expressed below.



As before, the shaded area indicates the possible losses under a new institutional arrangement compared with the old. Such losses are particularly likely at low levels of "inputs," expressed here in terms of institutional changes in the marketing arrangements themselves. If the shaded area represents the possible loss, the probability of this loss is simply the probability that output due to I* will be less than due to I.

The risk that the new maize marketing institution will lead to levels of output demanded lower than under the old arrangement is again the baseline concern. As before, the risk that I* may end up below I can be understood as a problem of the probability distribution of the two variables. If the levels of output I* and I are distributed with some expected value together with variance measuring both objective and subjective uncertainty, this information may be expressed as below:

For the old institution

$$E(I) = \mu_I \quad ; \quad V(I) = \sigma_I^2$$

For the new institution

$$E(I^*) = \mu_{I^*} \quad ; \quad V(I^*) = \sigma_{I^*}^2$$

The risk that I^* is less than I, or R_{I^*}, is the positive probability of lowered output.

(8) $$R_{I^*} = \text{Prob. } (I^* < I) > 0$$

This risk can be equivalently expressed as

(9) $$R_{I^*} = \text{Prob. } [(I^* - I) < 0] > 0$$

The term $\Delta T^* = (I^* - I)$ is the difference in output associated with the new and old institution, or institutional change. The probability that this change will lead to lowered output is a basic measure of institutional risk. As with technology, the process of institutional change may be described in terms of expected change and the variance attending it. This may be expressed as below.

(10) $$E(\Delta_{I^*}) = \mu_{I^*} - \mu_I$$

(11) $$V(\Delta_{I^*}) = \sigma_{I^*}^2 + \sigma_I^2 - 2\,\sigma_{I^*\,I}$$

Interpreting these results is somewhat more difficult than in the case of technology, for several reasons. First, institutional changes are nearly always associated with decisions involving a larger group than technological changes.[20] This implies that they involve interdependent social judgements which may be difficult to discern without considerable familiarity with the cultural and political context in which they are made. Second, these judgements are likely to be more deeply rooted

in tradition than many technological activities. These factors lead institutional innovations to lag behind technological innovations, setting up friction and disequilibrium where these processes are interdependent. This interdependence will be discussed in more detail below.

The expected impact of institutional change $E(\Delta_{I*})$ on output and incomes suggests that institutional risk R_{I*} will fall if $E(I^*) = \mu_{I*}$ is raised in relation to $E(I) = \mu_I$. In words, increased expected output and incomes associated with a new marketing institution can lower the risk attached to it the higher the comparative rewards of the new institution appear to be.

As above, an alternative way to lower this risk is to lower the variance or uncertainty associated with institutional change. As with technology, lowering $V(\Delta_{I*})$ can occur in any of several ways. First, it can result from increased confidence concerning the impact of the new institution, reflected by lower values of σ^2_{I*}. It can also result from increased confidence over the existing institutional arrangement, lowering σ^2_I. In general, since the new institution is untried, $\sigma^2_{I*} > \sigma^2_I$, and the ability of outside assistance to lower σ^2_I is in doubt. Hence, the majority of reductions in uncertainty must be due to raised confidence in the new institutional arrangement, lowering σ^2_{I*}. Finally, risk can be lowered by the positive covariance of new and old institutions, σ_{I*I}. This can be interpreted as similar response by both old institutions and new to factors affecting them such as climate or rainfall. Institutional alternatives which respond similarly to a variety of external shocks will be more familiar than those which respond in an opposite manner.

Like technological risk, institutional risk resulting from proposed change may constrain increases in output and the realization of net project benefits. Projects implemented with an eye for this risk need to attend to factors captured by (μ_{I*}, μ_I, σ^2_{I*}, σ^2_I, and $\sigma_{I*\,I}$).
A variety of policy interventions to be considered below are possible which will influence these factors and thus the level of risk. Combinations of policy instruments can then be chosen based on their relative cost.

Technological and Institutional Interaction

An important issue is the degree to which institutions and technology are linked. A more formal way of putting this question is in terms of the covariance between new and old technologies and institutions. If increased outputs due to new technology are associated with declines in output under existing institutions, then σ_{T*I} is negative. In effect, the new technology works at cross-purposes with existing institutions. Conversely, σ_{T*I} may imply a positive interaction between new technologies and existing institutions. Hence, relationships between technology and institutions may be positive or negative. Depending on both the sign and magnitude of these relationships, it is possible in principle to determine whether technologies and institutions are both in need of change simultaneously, or whether a phased approach is more appropriate. Rather than moving directly from TI to T*I*, more indirect routes may be required. An option may be to introduce only "technical packages" such as an improved maize

variety if it is compatible with the existing institutional structure. Another option would be a new marketing arrangement alone, if existing technologies are compatible with increased maize marketing. Like the other terms discussed in this section, estimates are not likely to be precise, but expressing the problem more formally helps focus attention in a systematic way on the relevant issues of implementation.

In summary, both technological and institutional risk may be described in terms which capture the problem facing farmers. The fundamental problem is: What is the probability that changes introduced by the project will lead to lowered output? Depending on attitudes toward this risk, farmers may not adopt new techniques or institutional arrangements and project benefits may be foregone. If such risks are binding constraints on project implementation a variety of policies may relieve these constraints. The role of project planning is not only to determine whether the constraints are binding, but to propose a cost-minimizing set of interventions designed to relieve them.

These include a variety of types of policy interventions. One type results in an increase in the level of output expected of the new technology or institutions. A second type results in reduction in uncertainty over these changes. A third type emphasizes components which are highly similar to existing ones. In addition, the relationships between technology and institutions merits scrutiny in implementation. Having identified the basic sources of risk and the types of approaches which may be necessary to reduce it, it is now useful to describe more formally how risk may constrain project implementation.

IV. Risk as a Constraint on Project Benefits

Whether technological and institutional risks actually constrain the realization of net project benefits is an empirical question of some importance. Strong evidence now exists that farmers are generally risk averse, especially in traditional farming communities.[21]. However, much research remains over the degree of risk aversion in different communities and among different farmers and farm households.

An even more important issue, seldom addressed, is how these attitudes are most effectively confronted at the level of project implementation. In the previous section, a simple analysis considered different levels of risk associated with new technologies and institutions. The analysis suggested that these risks are a systemmatic function of the comparative expected outputs under new and old approaches, the variances of these output levels, and the covariance or interaction between them. These factors, together with the interaction of technology and institutions, provide the basis of an implementation strategy reducing risk.

If risks act as a binding constraint on the adoption of T* and I*, it is reasonable to suppose that the point at which this is true differs across communities and individual farmers. The problem for project implementation is to determine the distribution of these attitudes in the project area, and how most cost-effectively to relieve risk constraints when they are binding.[22] The typical situation facing the farmer is succinctly described by Anderson:

> Positive opportunities, such as technological innovations, will appear and be available for uptake. Each will be reviewed by decision makers

and, on the basis of whatever information is at hand, personal judgement made about the extent and timing of possible exploitation. Farmers may feel that some innovations add more to the riskiness of their operations than they add to anticipated gains on average.[23]

In terms of project implementation, we may say that when risk is perceived to be excessive, the constraint this poses is "binding on the project," and that project components will not be adopted. For a given farmer or group of farmers, preferences for new technologies and institutions will be described by an individual or group utility function U_i, such that

(12) $$U_i = U_i(R_{T*}, R_{I*}).$$

In words, any farmer or farm household will define its utility (in part) as a function of particular attitudes toward technological and institutional risk.

Hence, if we seek to maximize the benefits of a particular project in terms of output and incomes, we must recognize that this maximization is constrained by the preferences of farmers. Since these preferences reflect attitudes toward risk, the problem of project implementation may be expressed as the maximization of expected net benefits subject to the constraint posed by these risks. For a given farmer or group of farmers, there are presumably some risk levels $\overline{R}_{T*}$ and $\overline{R}_{I*}$ which are too high to allow adoption of the proposed technology or institutions. Therefore, for these constraints to be non-binding it must be the case that

(13) $$R_{T*} < \overline{R}_{T*}$$

(14) $$R_{I*} < \overline{R}_{I*}$$

The constraints will therefore be binding whenever

(15) $$R_{T*} \geq \overline{R}_{T*}$$

(16) $$R_{I*} \geq \overline{R}_{I*}.$$

The lesson this suggests for project implementation is that efforts should be made to identify the threshold levels of risk $\overline{R}_{T*}$ and $\overline{R}_{I*}$ which will constrain project goals. This diagnostic activity is closely related to the approach followed by farming systems and extension efforts. In addition to focusing on technology, which is the primary concern of farming systems research, this analysis suggests the usefulness of a parallel diagnostic exercise for institutions.

Once farmers' attitudes toward risk are reasonably well established it is then possible to ask how such risks are to be reduced. As indicated above, a variety of approaches are possible which will depend on comparative costs in a given project and policy environment. To take a specific example, suppose a new high yielding maize variety is to be introduced together with the development of a new maize marketing board. Adoption of these changes is projected to yield increased maize output which when sold will increase farm incomes. These benefits, minus the costs of introduction and implementation, yield the net benefits of the project, discounted over the relevant time horizon. The maximization of these benefits is constrained by the risks of adoption perceived by farmers, however. Hence, the problem may be expressed as a constrained maximization exercise of the form below.

(18) $$\text{Maximize } E[Y(Q_i)] = E\left[\sum_{i=0}^{n} \frac{B(Qi) - C(Qi)}{\prod_{i} (1+r_i)}\right]$$

$$\text{subject to:} \quad \overline{R}_{T*} - R_{T*} \geq 0$$

$$\overline{R}_{I*} - R_{I*} \geq 0$$

The constraints imply that the levels of risk R_{T*} and R_{I*} must be less

than or equal to the thresholds $\overline{R}_{T*}$ and $\overline{R}_{I*}$. If they are not, then net project benefits will be constrained until either the threshold levels are raised (more risk is tolerated) or the risks perceived by farmers are lowered. In the interim, the project may be stalled. In addition to the constraints which technological and institutional risks may pose to adoption of a new maize variety or participation in a new marketing institution, the interaction between these constraints may be critical. Absence of marketing channels may dominate the project simply because they make high yielding maize unprofitable.

The thresholds at which risks bind adoption are not always uniform, since different preferences for risk will lead some farmers to adopt new technologies or participate in new institutions before others. Hence, depending on individual or group differences in $\overline{R}_{T*}$ and $\overline{R}_{I*}$ different adoption and participation rates will be observed. Furthermore, these thresholds of acceptable risk are sensitive to income, since farmers' behavior depends on their capacity to cover losses. Any program which increases output and income will be likely to increase this capacity.[24] If adoption of a new technology involves large fixed costs, for example, the ability to bear the risks associated with a particular threshold R_{T*} will be conditional on total assets. Therefore, depending on the distribution of both risk aversion and assets, a pattern of adoption would be expected in which those who are more risk averse would be likely to wait until those with higher risk thresholds have adopted the maize technology before doing so themselves. The information gained concerning expected increases in output (μ_{T*}) and

decreased uncertainty over expected output (σ_{T*}) would lower risk to those who adopt a "wait and see" posture. At the point where $R_{T*} < \overline{R}_{T*}$ the constraint to these late adopters would be overcome and would no longer bind adoption.

This sequence involves a learning process in which the individual farmer's decision to change results from sufficiently low levels of technological and institutional risks.[25] The sequence results from some farmers who go first, providing information and assurance to those that follow. This is a learning process describing not only rural development but technological and institutional innovation generally.[26]

In order to accelerate such process, the above analysis implies an implementation strategy built around three approaches. To return to our example of maize production and marketing, such a strategy would involve a balance between three main thrusts. First, HYV maize promising significant increases in expected returns, or marketing institutions which are expected to yield high levels of demand for output, can both be expected to reduce the risks of change to the farmer. However, even if increases in expected returns are high, significant levels of variance associated with the changes will raise the probability that the farmer will end up worse off. Hence, reductions in the variance of new technologies or institutions will also lower risk, implying that a "high pay-off" strategy alone may not suffice. Third, the higher the positive association between the old technology or institutions and the new, the less unfamiliar they will seem. Thus new technologies and institutions which are similar to existing production techniques and institutional arrangements will also lower perceived risks of change, and may be an important part of successful implementation.

Clearly, implementation based on these factors may involve trade-offs of one sort of risk-reduction for another. Project planners need to identify which combination is the most cost-effective set of interventions reducing risks. For example, less dramatic improvements in output under HYV maize may be traded for less variance respecting these improvements and/or greater similarity between the HYV technology and existing technology. On the institutional side, high levels of demand for marketed output may be traded for more certain levels, as well as for new marketing institutions which are similar to existing institutions. Finally, acknowledgement of the interdependencies of technology and institutions can lead to positive spillovers in which reductions in risks in institutional areas are associated with reductions in risks of new technology. In other words, if T* and I* are positively associated, then improved marketing opportunities will be associated with increased adoption of new maize varieties and vice versa.

From the point of view of the project as a whole, binding risk constraints imply that the project may fall short of its goals. Under circumstances in which these constraints are not binding, maximization of net project benefits would be achieved by setting expected discounted marginal benefits of increases in maize output equal to expected discounted marginal costs. But if the risk constraints <u>are</u> binding, optimal project implementation requires that a "risk factor" be acknowledged which will require additional project resources to overcome. Reducing this risk by attending to the factors described above will lead to projects with the highest overall effectiveness and efficiency in achieving increased output and incomes.

This analysis of risk suggests the value of information conveyed to farmers in the process of implementation. This has general implications for both public and private sector extension work and communication with farmers generally. Since risks relating to new technology and institutions are defined over output and, (given prices) income,[27] reductions in these risks are the result of information on both expected returns and the variance and covariance of these returns in connection with old and new technologies and institutions. Where risk constraints are binding, additional resources will be required to achieve the stated goals of the project. In economic terms, the information reducing these risks constraints is equivalent to a shift in the perceived supply (or demand) functions describing output changes and thus in net project benefits.[28]

Risk reduction thus provides a rationale for efforts to convey this information whether via extension systems, private marketing institutions, or communications efforts generally. The method by which information can best be conveyed is an essential issue for project implementation. In some cases, public extension systems may be less efficient in conveying this information than private seed companies. In other cases, private companies, by focusing on one aspect of the risks of change (generally expected returns) will fail to overcome them without attention to questions of variability and familiarity. An appropriate mix of policy and project measures reducing risks is thus fundamentally a question of the comparative efficiency of information transfer in a variety of different settings. An important lesson emerging from the managerial sciences is that decentralized, bottom-up decision making is more informationally efficient than more centralized approaches. This in turn

suggests that strategies of risk reduction will be more likely to succeed if they are implemented as close to the farm household unit as possible, rather than in the form of pronouncements from a central planning office.

Together, reducing technological and institutional risk may also provide a unifying theme for the twin development goals of technology transfer and institutional development.[29] By emphasizing the interdependence of technology and institutions at the project level, the analysis can help to operationalize general policy guidelines in specific settings. One of the key implications of this study is that neither technology transfer nor institution building efforts are likely to succeed unless they can be related specifically to the incentives of the farmer - the recipient and potential user of both new techniques of production and new institutional arrangements. Without an understanding of these incentives, project implementation will be a hit-or-miss enterprise.

V. Conclusion: Ten Questions for Project Implementation

If risk aversion by farmers is recognized as a significant constraint on the achievement of project benefits, much more weight must be placed on the reduction of these risks in project implemantation. The preceding analysis suggests a systematic basis for weighing the risks of technological and institutional change. The lessons for project implementation may be reduced to a series of ten questions relevant to all projects in which farmer risk aversion is suspected as a constraint.

Answers to these questions may be difficult to give with precision. However, the questions provide a guide to implementation, and a measure of ignorance about relevant details necessary to deal directly with farm household incentives. They yield a conservative ar cautious pproach to implementation based on a learning process focused directly on the farmer.

(1) What technologies (T*) and institutions (I*) are proposed by the project and what existing technologies (T) and institutions (I) are they to replace?

(2) What is the expected output (and income at projected prices) resulting from existing technologies and institutions, and how does this compare to projected output expected under the new technologies and institutions?

(3) What are the confidence intervals defined by farmers around the output and incomes expected under the existing technology and institutions, and what are the corresponding intervals defined around the expected output under the new technology and institutions?

(4) What is the estimated probability (or range of probabilities of different groups) that the output and incomes resulting from the new technology and institutions will fall below that of existing methods?

(5) Is this probability (or probabilities for particular groups) sufficiently high to pose a constraint to the realization of net benefits of the project?

(6) Do the new technology and the old (T* and T) and the new institutions and the old (I* and I) respond similarly or differently to outside factors such as changes in climate or rainfall?

(7) Are the new technology and the old institutions (T* and I) and the old technology and the new institutions (T and I*) likely to interact positively or negatively?

( ) What is the cost-minimizing mix of policies reducing risk to the farmer to a level such that they are no longer binding constraints, and what steps are necessary to implement this mix of policies respecting both private and public transfers of information to farmers?

(9) Given this mix of policies, what proportion of project funds need to be devoted to reducing overall risks to implement the recommended policies?

(10) Over what time period is the proposed reduction in risks and concomitant realization of net project benefits to be achieved?

These questions can serve as the basis for more orderly and systematic attention to issues of risk and uncertainty in project implementation. If, as this study argues, the risk of change poses a major disincentive to farmers'

adoption of project components, the resources devoted to its reduction may make substantial advances in projects possible. The natural basis for such policy is an expanded effort by extension as well as representatives of the private sector to lower the perceived risks of change. This implies larger outlays for both extension and/or private sector developments directed toward this goal. Such outlays, if properly focused and directed, may achieve substantial increases in the rate of technical and institutional change in the years ahead.

Footnotes

1. Among the important early contributions in water projects analysis were Otto Eckstein, Water Resource Development - The Economics of Project Evaluation, Cambridge, Harvard University Press, 1958; John V. Krutilla and Otto Eckstein, Multiple Purpose River Development, Baltimore, Johns Hopkins University Press, 1958; Roland N. McKean, Efficiency in Government through Systems Analysis, RAND Corporation Study, New York, John Wiley and Sons, 1958; J. Hirschleiffer, J. C. de Haven, and J. W. Milliman, Water Supply - Economics, Technology and Policy, Chicago University of Chicago Press, 1960; R. H. Haveman, Water Resource Investment and the Public Interest, Nashville, Vanderbilt University Press, 1965.

2. Jan Tinbergen, The Design of Development, Economic Development Institute, The World Bank, Baltimore, Johns Hopkins Press, 1958.

3. Tinbergen's emphasis on the "capital coefficient," or ratio between capital and net national income or output reflected the growth orientation of the post-war period. As Tinbergen noted: "the aim of development is not simply to increase national income but also to increase national income per capita" (1958, p. iv). By this argument, higher levels of capital investment are required the lower the capital coefficient and the higher the rate of population growth. The role of the project was to assist in this capital formation.

4. This literature is now huge. The early handbooks to project appraisal include I. M. D. Little and J. A. Mirlees, Manual of Industrial Project Analysis in Developing Countries, Volume II, Social Cost-Benefit Analysis, Development Center, OECD, Paris, 1968; P. Dasgupta, A. K. Sen and S. Marglin, Guidelines for Project Evaluation, UNIDO, Vienna, Project Formulation and Evaluation Series, No. 2, U.N., New York, 1972, and a sequel to the Little and Mirrlees volume, Project Appraisal and Planning for Developing Countries, New York, Basic Books, 1974. Other prominent contributions include A. K. Dasgupta and D. W. Pearce, Cost-Benefit Analysis: Theory and Practice, London, MacMillan Student Edition, 1972, E. J. Mishan, Cost-Benefit Analysis, revised new edition, London, Allen and Unwin, 1975 and L. Squire and H. G. Vander Tak, Economic Analysis of Projects, The World Bank, Baltimore, Johns Hopkins University Press, 1975. Two useful guides are N. Imboden, A Management Approach to Project Appraisal and Evaluation, Development Center, OECD, Paris, 1978; and Depak Lal, "Methods of Project Analysis: A Review," World Bank Staff Occasional Paper, No. 16, 1974.

5. Depak Lal, ibid. note 4, p. XIV.

6. The operational guide to agricultural appraisal at the World Bank is J. Price Gittinger, Economic Analysis of Agricultural Projects, Economic

Development Institute, The World Bank, Baltimore, Johns Hopkins Press, (newly revised) 1982. At AID, it is Handbook 3: Project Assistance, Washington, (revised), 1982. The World Bank favors an income-weighted version of the internal rate of return criterion as a basic indicator of net benefits. The AID handbook (Appendix 1-A) recommends consideration of multiple criteria including benefit-cost ratios, internal rates of return, and cost-minimization. Both documents refer to the necessity for qualitative documentation of other social and economic benefits.

7. This discussion is intentionally simplified to convey the essential welfare underpinnings of project appraisal methods. For an excellent detailed treatment of theory and policy, see R. Just, D. L. Heuth, and A. Schmitz, Applied Welfare Economics and Public Policy, Englewood Cliffs, N.J., Prentice-Hall, 1982. The application of theory to project appraisal in a development context is described in F.L.C.H. Helmers, Project Planning and Income Distribution, Studies in Development and Planning, Vol. 9, Boston, Martinus Nijhoff Publishing, 1979. An earlier survey of the different methods use in project appraisal is Lal, op. cit., note 4.

8. As Lal (op.cit., note 4, xiv) notes, the requirements for efficiency in this sense are stiff. In particular, for a given distribution of income, a perfectly competitive economy with no uncertainty about future tastes, institutions and technologies must exist. Under these circumstances, market prices of goods and factors would equate the marginal social cost of producing and the marginal social value of using the relevant goods and factors. For an investment project which is truly marginal (which does not affect output or input prices), the values of the output and inputs at market prices would provide the data necessary to determine the net present value of the project. In other words, market and "shadow" prices would be equivalent, and would yield Pareto optimality for all inputs and outputs for which markets exist.

9. Lal, ibid, note 4.

10. See the "Symposium on the Little-Mirrlees Manual of Industrial Project Analysis in Developing Countries," Bulletin of the Oxford University Institute of Economics and Statistics 34 (1972). Earlier criticisms of some issues of shadow pricing and project evaluation include Peter Wiles, "Growth versus Choice." The Economic Journal, 66 (June, 1956): 244-255; S.V. Ciriacy - Wantrup, "Benefit-Cost Analysis and Public Resources Development; Journal of Farm Economics 37 (November, 1955): 676-689; and Timothy King, "Development Strategy and Investment Criteria: Complementary or Competitive?," Quarterly Journal of Economics 80:1 (February, 1966): 108-120.

11. See A. K. Sen, The Choice of Technique, Oxford, Basil Blackwell, 1975; and Sen, "Control Areas and Accounting Prices: An Approach to Economic Evaluation," The Economic Journal 82 (March, 1972): 486-501.

12. See F.L. C.H. Helmers, op. cit., note 7.

13. For general discussions of these issues see Squire and van der Tak, op.cit., note 4, P-17. See also Schlomo Reutlinger, "Techniques for Project Appraisal Under Uncertainty," World Bank Staff Occasional Paper No. 10, Baltimore, Johns Hopkins University Press, 1970, and Louis Y. Pouliquen, "Risk Analysis in Project Appraisal," World Bank Staff Occasional Paper No. 11, Baltimore, Johns Hopkins University Press, 1970. Unfortunately, none of these treatments focuses on the risks of the project to farmers, or how these risks should be reduced.

14. This definition follows a recent discussion by Milan Zeleny in Multiple Criteria Decision Making, New York, McGraw-Hill, 1982. Zeleny approvingly quotes E. Lerner, who notes that some writers unfortunately look upon variance not only as a measure of variability but of risk, which it is not. "Risk," Lerner notes, "is the probability of a loss or the probability that a return will be lower than some target level." See E. Lerner, Managerial Finance, Harcourt Bruce Jovanovich, New York, 1971, p. 328.

15. John McInerney, The Technology of Rural Development, World Bank Staff Working Paper No. 295, October, 1978.

16. Ibid., pp. 13-14.

17. Ibid., p. 13. A larger view of this issue is described in Mancur Olson, "Rapid Growth as a Destablizing Force," Journal of Economic History, 27 (Dec., 1973): pp. 529-52 and R. Easterbrook, "Uncertainty and Economic Change, Journal of Economic History 14 (1954): 346-360.

18. A comprehensive recent survey of the evolution of AID and World Bank approaches to institutional and technology change is Anne O. Kreuger and V. W. Ruttan, The Impact of Development Assistance, a report prepared for the Department of State and Agency for International Development, draft, December 30, 1982.

19. The analysis is a simple adaptation of Kelvin Lancaster's approach to consumer theory and the general approach to programming described as "activity analysis." See K. J. Lancaster, "A New Approach to Consumer Theory," Journal of Political Economy, 74 (1966): 132:157. Frances Stewart has used a simple characteristics model to describe technological choice in Technology and Underdevelopment, London, MacMillan, 1977.

20. Leonid Hurwicz describes this problem as individual versus group "incentive compatibility." Technical innovations are nearly always compatible with the incentives of a individual entrepreneur. Institutional changes involve altering the incentives of larger numbers. See Leonid Hurwicz, "On Informationally Decentralized Systems," in McGuire and Radner (eds), Decision and Organization, North Holland, Amsterdam, 1972. For a discussion in relation to technological and institutional change, see Carlisle Ford Runge, Vernon W. Ruttan and Leonid Hurwicz, "Sources of Institutional Innovation: An Interpretive Essay," Discussion Paper, Department of Economics, University of Minnesota, 1983.

21. Jock Anderson, "Nature and Significance of Risk in the Exploitation of New Technology," Proceedings of the International Workshop on Constraints to Development of Semi-Arid Tropical Agriculture, Feb. 19-23, 1979, Hyderabad, India, ICRISAT, 1080, p. 298. The growing literature on risk includes a number of well-established studies, such as A. Johnson, Sharecroppers of the Sertao, Palo Alto, California, Stanford University Press, 1971; G. O'Mara, A Decision -Theoretic View of the Microeconomics of Technique: Diffusion in a Developing Country, Ph.D. Thesis, Stanford University, 1971; E. Moscardi and A. de Janury, "Attitudes Toward Risk Among Peasants: An Econometric Approach," American Journal of Agricultural Economics 59 (1977): 710-716; T. Wiens, "Uncertainty and Factor Allocation in a Peasant Economy," Oxford Economic Papers 29 (1977): 48-60; H. P. Binswanger, "Risk Attitudes of Rural Households in Semi-Arid Tropical India," Economic and Political Weekly 13:25 (1978): 49-62; J. L. Dillon and P. L. Scandizzo, "Risk Attitudes of Subsistence Farmers in NOrtheast Brazil: a Sampling Approach," American Journal of Agricultural Economics 60 (1978):425-435.

22. H. P. Binswanger, N. S. Jodha and B. C. Barah report that in areas of the semi-arid tropics, there is not enough difference in technological risks perceived by small versus large farmers to merit separate approaches. However, institutional constraints do differentiate the two groups. See "The Nature and Significance of Risk in the Semi-Arid Tropics," in ICRISAT Proceedings, op.cit. note 21, pp. 303-316.

23. Anderson, op.cit., note 21, p. 298. See also O'Mara. op.cit., note 21; R. K. Pevrin, E. R. Moscardi, P. L. Winkelmann and J. K. Anderson, "From Agronomic Data to Farmer Recommendation: an Economics Training Manual," CYMMYT Information Bulletin 27, Postal 6-641, Mexico 6, 1976; C. H. Gladwin, "Allocative Efficiency and Decision Models," International Fertilizer Development Center Working Paper, Florence, Alabama, 1978.

24. Sara Berry, "Decision Making and Policymaking in a Rural Development," in Agricultural Decisionmaking, P. Bartlett (ed.), Atlanta, Emory University Press, 1980. Berry also asserts that without changes in relationships of power and patronage, information per se may be insufficient to induce adoption, although whether these power relationships are within the control of the project is doubtful.

25. Gershon Feder and Gerald T. O'Mara, "Farm Size and the Diffusion of Green Revolution Technology," Economic Development and Cultural Change 30.11 (Oct., 1981): 59-76. See also Wayne Schutjer and Harlin G. Van Der Veen, Economic Constraints on Agricultural Technology Adoption in Developing Nations, U.S. AID, Occasional Paper no. 5, Washington, 1977.

26. Nathan Rosenberg treats the issue of technological expectations and learning in "On Technological Expectations," Economic Journal 86 (1976): 523-535. Numerous approaches to institutional change as an evolutionary learning approaches exist. See, for example, David Korten, "Community Organization and Rural Development: A Learning Process Approach," Public

Administration Review 40 (Sept. - Oct., 1980): 480-511; Frances Korten, "Building National Capacity to Develop Water Users' Associations Experience from the Philippines," a paper prepared for the World Bank Sociological Workshop, Washington, D.C., July 27, 1981; Kenneth G. Swanberg, "Institutional Evolution: From Pilot Project to National Development Program - Puebla and Caqueza," Development Discussion Paper No. 132, Harvard Institute for International Development, March, 1982.

27. Binswanger, Jodha and Barah, op.cit., note 22, report that in their studies, most income risks come from output (yield) variations rather than from price variation. However, nothing precludes the extension of the analysis to include price risks as well.

28. Y. Hayami and W. Peterson, "Social Returns to Public Information Services: Statistical Reporting of U.S. Farm Commodities," American Economic Review 62 (1972): 119-130, Ludwig M. Eisgruber, "Developments in the Economic Theory of Information," American Journal of Agricultural Economics 60:5 (December, 1978): 901-905.

29. A recent AID policy paper expressing agency approaches to institution building efforts is "Institutional Development," Bureau of Program and Policy Coordination, U.S. Agency for International Development, Washington, D.C., March 1983. At this writing, a similar policy paper on technology transfer is forthcoming.

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"Weighing the Risks of Change: Technology, Institutions and Project Implementation"

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Executive Summary

Introduction

For those used to the comparative stability and certainty of life in a developed economy--even those who have grown up with agriculture--the risks faced by farmers in LDC's may be difficult to appreciate. When technologies are proposed which promise higher returns, the risks which may attend the adoption of these techniques to the farmer are often overlooked. When new institutions are introduced, such as credit or marketing boards, the general environment of institutional uncertainty in which traditional farmers operate often makes these changes seem highly risky compared with established institutional arrangements. These risks are an important aspect of project implementation which deserve more careful analysis.

This paper examines the relationships between farmer risk aversion and the implementation of projects. It is divided into four major sections. The first examines the project as an agent of change in rural areas - the source of supply of new technologies and institutions. It links the project design concept to cost benefit analysis, and explores the difficulties of treating technology and institutions as fixed in relation to project goals. The second section examines the impact of the project in terms of the risks it may pose to farmers using traditional technologies and institutions, and provides a theoretical basis for decomposing such risks into their separate elements.

The third section considers how these risks may act to constrain the achievement of project goals, and how such constraints may affect the capacity to transfer technologies and institutions. The analysis of the second section is then applied to indicate the types of efforts necessary to lower risks perceived by farmers in the implementation of the project. The fourth section concludes with an agenda for further policy research, based on ten questions relevant to project implementation. By focusing directly on these questions, projects can attend to the specific factors most likely to accelerate the process of technology transfer and institutional change by overcoming risks attached to these changes by farmers.

General Implications

The general implications of this research for project implementation may be summarized as follows.

1. In the project setting, technology and institutions are clearly variables. This implies that technological and institutional change are part of project implementation. Technological and institutional change raise risks to farmers. Risks are defined as the likelihood or probability that outputs and incomes will fall below some threshold level. The farmer adopting a new seed or taking part in institutional reform wants to know how likely it is that he or she will end up better off for the change. If "better" is defined by reference to output and incomes with existing technology and institutions, then this baseline is the standard or threshold by which the risks of change are judged.

2. Project implementors must therefore identify the specific technological and the institutional changes necessary to achieve project benefits. Traditional economics has not been terribly helpful because both technology and institutions are taken as given. If we propose to introduce a new HYV of maize or a new marketing structure or set of credit institutions, such a static approach will not suffice. The very definition of the project involves dynamic changes in these variables.

3. After the changes have been identified, it must be recognized that new technologies and institutions will create major questions in the minds of the recipients of project aid. These questions may be expressed as risks associated with the adoption of a new maize variety, for example, or with participation in a new marketing or credit institution. This is consistent with a variety of empirical studies which show that the risks of technological and institutional change are often major constraints on the achievement of project goals. Here AID's traditional tools of analysis -- such as the log-frame -- are not of much use since they fail to focus specifically on the risks perceived by farmers.

4. Project implementors must then identify whether these risks pose constraints to the achievement of project goals. How much change can farmers tolerate before the risks of a new way of doing things becomes too high, and they fail to adopt them? To project recipients, the question is more straightforward: What is the likelihood (or probability) that a new maize variety or a new marketing institution will lead to levels of output and income <u>lower</u> than what they have already? If the perceived or actual likelihood, i.e., the risk, <u>is</u> a constraint on the achievement of project goals, then the project cannot move forward.

5. In project implementation, there are three major methods of risk reduction. The first is to raise the expected returns resulting from technological and institutional innovation. The second is to reduce the variability surrounding these returns, raising confidence in the methods to be transferred. The third is to introduce technology and institutions with general characteristics similar to existing methods. To take the example of a HYV of maize and new marketing scheme, farmers' willingness to plant the seed and participate in marketing is a result of overcoming three types of problems. First is the expected difference between average levels of output grown and marketed under the project compared with the status quo. The greater this difference, the less the perceived risks of adopting the new technology and institutions. Second, substantial gains of this "high-payoff" type will be traded for smaller gains, if these gains are assured. Thus, risks also fall if the variability of the seed or marketing institutions performance is low. Third, either of these features may be traded off if the proposed seed or marketing institution is highly familiar to the farmer, and reacts predictably to typical influences in the environment. If risks constrain the achievement of project goals, then credit, factor prices, stable government policies, and effective extension efforts may all be used to reduce risk by increasing expected returns, reducing variability, and identifying methods which are similar to existing techniques or institutions.

6. More generally, lowering risks requires implementation based on accurate and complete information designed to provide answers to farmers' questions, which arise by attempts to promote accelerated rates of change. By

providing improved information, for example, successful on-farm research and extension systems together with efficient systems of market prices can rapidly accelerate project development. Current emphasis on decentralized, bottom-up institutions is also explicable in these terms, since they are often more informationally efficient compared with unwieldly, top-down authority. Furthermore, decentralized approaches to project implementation create grass-roots demands for technical and institutional change. This suggests a need to reexamine the role of extension and communication with farmers generally. If extension and communication efforts can reduce farmers' risks, more rapid transfers of technology and acceptance of new institutions may result, increasing the benefits of project assistance.

In sum, the implementation of the project may be understood as a three step learning process. This paper provides an analytical foundation for such an evolutionary or learning approach to project implementation. First, the technical and institutional risks perceived by farmers must be identified. Second, these risk constraints can then be addressed as questions of returns, variability, and familiarity of technologies and institutions. Finally, policies can be implemented which raise returns, reduce variability, and increase familiarity with the new technologies and institutions. By identifying risks as constraints to the implementation of projects, greater emphasis can be given to policies which slowly remove these constraints over time. Policies which systematically reduce risk will stimulate incentives to adopt both new technologies and new institutions beyond the life of the project itself.

Ten Questions for Project Implementation

If risk aversion by farmers is recognized as a significant constraint on the achievement of project benefits, the lessons for project implementation may be reduced to a series of ten questions.

Answers to these questions may be difficult to give with precision. However, the questions provide a guide to implementation, and a measure of ignorance about relevant details necessary to deal directly with farm household incentives. They yield a conservative and cautious approach to implementation based on a learning process focused directly on the farmer.

(1) What technologies and institutions are proposed by the project and what existing technologies and institutions are the to replace?

(2) What is the expected output (and income at projecte prices) resulting from existing technologies and institutions, and ho does this compare to projected output expected under the new technologies and institutions?

(3) What are the confidence intervals defined by farmers around the output and incomes expected under the existing technology and institutions, and what are the corresponding intervals defined around the expected output under the new technology and institutions?

(4) What is the estimated probability (or range of probabilities of different groups) that the output and incomes resulting from the new technology and institutions will fall below that of existing methods?

(5) Is this probability (or probabilities for particular groups) sufficiently high to pose a constraint to the realization of net benefits of the project?

(6) Do the new technology and the old and the new institutions and the old respond similarly or differently to outside factors such as changes in climate or rainfall?

(7) Are the new technology and the old institutions and the old technology and the new institutions likely to interact positively or negatively?

(8) What is the cost-minimizing mix of policies reducing risk to the farmer to a level such that they are no longer binding constraints, and what steps are necessary to implement this mix of policies respecting both private and public transfers of information to farmers?

(9) Given this mix of policies, what proportion of project funds need to be devoted to reducing overall risks to implement the recommended policies?

(10) Over what time period is the proposed reduction in risks and concomitant realization of net project benefits to be achieved?

These questions can serve as the basis for more orderly and systematic attention to issues of risk and uncertainty in project implementation. If, as this study argues, the risk of change poses a major disincentive to farmers'

adoption of project components, the resources devoted to its reduction may make substantial advances in projects possible. The natural basis for such policy is an expanded effort to lower the perceived risks of change. This implies larger outlays directed toward this goal. Such outlays, if properly focused and directed, may achieve substantial increases in the rate of technical and institutional change in the years ahead.