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Behavior Under Uncertainty And Public Policies In Peasant Agriculture: Applications Of Economic Theory Of Uncertainty

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BEHAVIOR UNDER UNCERTAINTY AND PUBLIC POLICIES IN PEASANT AGRICULTURE: APPLICATIONS OF ECONOMIC THEORY OF UNCERTAINTY

by

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ABSTRACT

This thesis fulfills a three-fold purpose. First it analyses the implications of agricultural uncertainty on peasant decision making. Specifically, it considers production and migration decisions and explains the role of several peasant practices and institutions in these contexts. Second, it investigates the impacts of various public policies on peasant's behavior. In this connection, a number of public policies including institutional reforms, fiscal policies and investments in agriculture, and social services are considered. Third, it suggests suitable modifications in the existing public policies and recommends new measures in the light of the theoretical results obtained. These include effective implementation of land reforms, systematic investments in minor irrigation and other risk-reducing measures as well as social services and introduction of a crop insurance program along with progressive agricultural income taxation.

The present study is essentially an application of the economic theory of uncertainty to peasant decision-making. In the introductory chapter a brief description of the role and significance of uncertainty in peasant agriculture is presented.

A simple decision model of a typical peasant farmer, facing output uncertainty is introduced in chapter two. After deriving the implications of uncertainty on his

factor use, the effects of various public policies on his behavior are investigated. This investigation is done essentially in a comparative static framework. Wherever possible these results are compared with the standard policy prescriptions based on deterministic models. In a number of cases, it is argued that optimal policies are different from the existing ones. Further, the model is generalized to include input uncertainty also.

Chapter three deals with the specific problem of rural-urban migration. For this, a modified version of the model of chapter two is presented. Unlike the standard theory of rural-urban migration, where only the urban income is treated as uncertain, in the present analysis the main stress is on the uncertainty of farm income. Within this framework, the peasant behavior as regards to migration is analysed. The effects of a number of public policies including investment in agriculture, land reform and income tax, on migration are studied.

Some of the policies discussed in chapters two and three have direct bearing on the elimination or reduction of the impact of uncertainty. But elimination or reduction of agricultural uncertainty may not be always feasible or desirable. In such cases the best solution would be to transfer the risk to an agency best able to bear this risk. The social and private benefits of such risk-transfer may well exceed the costs.

Taking these facts into account, in chapter four a general equilibrium theory of crop insurance is developed. It begins with clarifications of certain conceptual and analytical issues which demonstrate the need for a separate theoretical analysis of crop insurance. Then, some theoretical justifications for the non-existence of crop insurance markets is provided. And finally, a theoretical model of a public crop insurance is developed and its properties analysed.

In chapter five the role of insurance in general and crop insurance in particular is discussed. Also, the distinct problems of crop insurance are presented and the traditional insurance surrogate institutions and practices analysed. Further, a viable crop insurance program specifically, in the context of India, is developed.

The final chapter attempts a brief appraisal of the findings and their relevance to practicing development planners and policy makers. Also, the limitations of the study and the scope for further theoretical and empirical investigations are indicated.

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CHAPTER 1

INTRODUCTION

The twin objectives of most developing countries are economic growth and social justice. As the largest economic sector in these countries, agriculture can play a key role to achieve these objectives. However, from a careful scrutiny of the developmental efforts during the last quarter century, one gets the impression that barring few important exemptions, most countries treated agriculture as an obstacle to be overcome rather than as a foundation upon which to build. Further, wherever there were development programs directed at agriculture, the benefits have in general accrued to a minority of wealthy farmers.

An immediate result of heavy emphasis on growth through industrialization has been increased income differentials between urban and rural areas. In many cases, the abject poverty in rural areas has resulted in large-scale migration to urban centres. Another aspect of industrialization is the wrong choice of technique. In majority of the cases, the technology adopted was capital-intensive, even when huge back-log of unemployment and underemployment existed.

Within the agricultural sector also, the income inequality between the very rich and the vast majority of the poor has increased as a result of the preferential treatment received by the former. Further, certain public policies, like subsidization of agricultural mechanization, resulted in substantial labor replacement which led to staggering rural poverty or enhanced urban unemployment.

Thus most of the benefits of developmentprograms bypassed a significant segment of the population in developing countries, namely peasantry, which constitutes more than sixty percent of the population in most of these countries. They still remain largely outside the entire development effort, neither able to contribute much to it, nor benefit fairly from it. Also, in countries where significant real economic growth took place, considerable portions of the gains were absorbed by the unprecedented population growth which took place during the last three decades. In short, even after a quarter century of efforts by the domestic governments and international community, the problems of economic development and economic equity looms large for more than half the world population. Apart from the staggering human misery involved, these problems create acute social tensions within and between regions and countries which threaten the very foundations of civilization.

It may be uncharitable to the economic science and the profession to argue that all these problems are the results of the application of mistaken theories and misplaced public priorities. However, a thorough scrutiny of the public policies pursued by many of the developing countries, clearly indicates that the policy prescriptions based on deterministic economic models were faulty. Thus, apathy towards new techniques and inputs, bonded labor, share-cropping tenancy, division of single holding into several scattered plots, payment of interest on loan in kind at a higher rate than in cash and many other conventional practices and institutions could not be explained. To brand the peasantry as 'irrational' or 'change-resistant' and to ignore them, when their economic behavior could not be explained by the conventional economic theory was a serious fault.

An important aspect of peasant life is the unsteady nature of income. Uncertainty of income, especially in tropical societies, is mainly due to the vagaries of nature. This uncertainty plays a critical role in peasants' economic decision making. Most of the economic and social institutions and even their religious beliefs and spiritual outlooks are characterized by this important factor. Any serious attempt at explaining peasant rationality and formulation of economic policies for the uplift of the peasantary should take this important factor into consideration.

The purpose of this thesis is threefold: First, to analyse the implications of agricultural uncertainty on peasant decision making. Specifically, we consider the production decision and migration decision and explain the role of several peasant practices and institutions in these contexts. Our second purpose is to explore the impacts of various public policies on peasants' behavior. Here we consider several public policies including institutional reforms, investments in agriculture and social service sectors and fiscal policies. Our third purpose is to suggest suitable modifications in the existing public policies and to recommend new measures in the light of the theoretical results. This includes effective implementation of land reforms, systematic investments in minor irrigation and other risk-reducing measures as well as social services and introduction of a crop insurance program along with progressive agricultural income taxation.

The present chapter contains a brief description of the role and significance of uncertainty in peasant agriculture and presents the methodology and scope of this study. Chapter two is devoted to the development of a theory of peasant farming under uncertainty. Initially the discussion is restricted to output uncertainty alone, but subsequently simultaneous uncertainty in output and inputs are introduced. In chapter three the impacts of agricultural output uncertainty on rural-urban migration are explored. In chapter four a general equilibrium theory of crop insurance is developed as a public policy.

Chapter five is devoted to a discussion of the role of agricultural insurance in peasant economies. The final chapter offers some concluding remarks.

As should be expected of any theoretical study of this kind, the policy conclusions are of general nature. Results are not developed to the level of policy prescriptions, but rather, the more modest goal is pursued of providing a better understanding of the implications of various public policies under uncertainty.

I.1. Uncertainty and Economic Theory

Almost every mode of economic behavior is influenced by uncertainty. The farmer faces uncertainty about weather as well as the output price; the entrepreneur in a mechanised industry is not affected that much by the vagaries of weather, but he may have to cope with the vagaries of the employees or break-down of machines; the number of customers visiting a store on any day is random; at the country level, the foreign demand for its products may be stochastic, or the foreign supply of raw materials may be random. Yet, it is only recently that the economist has begun to analyse the decision making of individuals under conditions of uncertainty.

In the past few decades, economic theorists have become progressively engaged in developing models to account for the presence and impact of uncertainty. In conventional micro models past and future are collapsed into the present and the current environment is assumed to be perfectly perceived by everyone concerned, at no cost. In such models there is little scope for past experiences and anxieties for the future, lack of knowledge and control over the environment, paucity and cost of information and hopes and regrets of the individual.

The theory of decision making under uncertainty tries to explain one's choices among alternative courses of action in situations where an action does not uniquely determine the outcome. In other words, the theory deals with choices among probability distributions. When one describes decision making under uncertainty as a choice among probability distributions, one assumes implicitly that the decision maker is able or willing to assign probabilities to the different outcomes which can result from his decisions. In deterministic theory it is not customary to differentiate between actions and their consequences since the two have one to one correspondence. In the theory of choice under risky conditions, one of the chief problems is the description of consequences which are not certain and therefore certainly not uniquely related to actions.

Uncertainties affect economic behavior and behavior, in turn, influences the incidence of uncertainty. Indeed, this could be an economic rationalization for the belief in 'Karma'.[1] An individual's choice of action in any context depends upon his subjective or objective belief about the results and when there is uncertainty about this for at least some options, upon his attitudes with respect to the bearing of risk. The behavioral mode based on the theory of risk aversion[2] has emerged as perhaps the most important analytic contribution of the uncertainty view and it has been already applied to a considerable spectrum of economic settings.

I.2. Uncertainty and Peasant Agriculture

A survey of the theoretical literature on uncertainty clearly indicates that most of the models are based in the context of financial markets and modern competitive firms, though it is well-known that agriculture is a prime example of an area involving uncertainty. Agriculture is subject to exceptional elements of uncertainty. These are partly due to the hazards inseparable from an industry which is based on natural-biological processes. There are a few recent studies in agricultural economics where uncertainty theories found their applications. A brief critical survey of this literature is attempted subsequently.

Though the effects of natural hazards on farming are now considerably reduced in developed countries, agriculture in most developing countries still depends to a large extent on the hazards of nature. For obvious reasons, deterministic models are not suitable to explain many features of the economic behavior of peasants in these societies. Apathy towards new techniques and inputs, bonded labor, share-cropping tenancy, a single holding divided into several tiny patches, payment of interest on loan in kind at a higher rate than in cash and many other conventional practices and institutions remain unexplained or rest as issues of theoretical controversy.

Indeed, the usual 'tradition-bound poor-peasant' explanation of lack of innovation, in many countries, has led to a policy of directing agricultural development programs towards the relatively wealthy farmers.[3] This growth-oriented approach worsened rural inequalities in some areas where agricultural progress has been substantial, as revealed by recent empirical studies.[4]

An attempt is made in the present study to show that if peasants are considered as essentially operating under conditions of uncertainty, most of the apparently irrational behavior can be given economic rationalization.

Innovative behavior, particularly in agriculture, involves added uncertainty. The situation is made riskier, because frequently a combination of new techniques and inputs is necessary for the individual items to have beneficial effects. Thus a high-yielding variety of rice, particularly sensitive to pests, may prove to be disastrous in the absence of proper pesticides. Similarly, in an inadequately watered region, fertilizer raises the average output as well as the variability of output.

The risk of harvest failure, like any uninsured risk, assumes immense proportions for a poor farmer. A good harvest may mean a better standard of living for him and his family for a season. But a bad harvest may imply any one or more of the following: a) semi-starvation, b) crippling burden of debt, c) 'distress' sale of his land well below the market price or d) bonded labor for himself and his family. In most of the peasant societies, the collapsing extended family system has not been replaced by public protection from private disaster. It is well known that risk premium[5] is an increasing function of risk and a decreasing function of assets. Indeed, poor farmers, because of their very poverty itself, may be more risk averse than rich farmers and hence shy away from innovation and change.

The reduction in family holding size, as population grows, will increase the sensible safety-first[6] propensities of the farmer. Because of unprecedented population growth, in most of the tropical agriculture, each new generation of rural decision-makers inherits a man-land ratio almost double that of its immediate predecessor.

In the above context most of the seemingly paradoxical institutions and practices in traditional economies may be manifestations of the extreme risk averse behavior of the poor. Also, many superficially odd peasant practices may make sense as disguised forms of insurance. Thus it is clear that any meaningful model used to explain peasant behavior and to prescribe public policies should explicitly take account of uncertainty. Before introducing the methodology and scope of our study, a short historical perspective appears to be in order.

I.3. Role of Agriculture in Economic Development - A Retrospection

The history of modern economic growth and development is essentially a history of industrialization. Most of the present-day developed economies started their growth by stepping up investment in industries. To a large extent resources and manpower for industry were drawn from agriculture, though part of the resources might have come from mercantile capital. The centre of gravity of the economy shifted from agriculture to industry and land lost its significance as the limiting factor of growth. The key input of industry was capital; but capital was ever-growing in laissez-faire capitalist economies. Indeed, the main concern of the classical economists, namely economic growth, ceased to be a problem. Also, the relevance of the dire consequences of Malthusian population dilemma was lost to most of the industrial world. The man-land ratio in agriculture gradually diminished due to industrial labor absorption and migration to the new world.

The succeeding generations of economists concerned themselves with the task of developing a theory to deal with the efficient allocation of resources in a market economy. One of the implicit conclusions of the neo-classical economic theory is that saving and investment are always forthcoming to assure a reasonable level of economic growth. Also, the question of income distribution was never an integral part of the modern economic theory. The tacit assumption was that in an ever-growing economy, incomes should be increasing for everybody, anyway. Further, any inevitable income transfers were assumed to be achieved by private charities supplemented by government's non-distortionary income redistribution programs.

Perhaps the most important post-war phenomenon on the international scene is the emergence of a large number of developing countries, as separate economic entities. Most of them are former colonies of the industrialized countries and together they contain more than two-thirds of the world population. Though these countries vary widely in economic and other characteristics, there are a few striking economic characteristics common to almost all of them: 1) Vast majority of the population depend on agriculture for their living, 2) In most of these countries farming is a way of life rather than an economic enterprise in the modern sense except for some plantation industries, 3) In most cases output and income from farming are very uncertain due to meteorological conditions and other natural hazards, 4) Many of these countries, though not all, experience very high man-land ratio in agriculture and 5) All of them have strong desire for achieving fast economic development.

The branch of modern economics, usually referred to as 'development economics' is the result of a good number of economists' attempts during the past few decades to find an answer to the problem of underdevelopment of these countries. Almost all pioneers in this field identified the main obstacle to development as the problem of low savings and investment in industries.[7] A number of theories have been developed to explain the existing phenomena and to suggest solutions.[8]

Though there are considerable differences in approaches and underlying assumptions, the policy prescriptions based on these models are invariably the same, namely mobilise resources, as much and as fast as possible, and invest them in industries. For most of the eminent development economists, the inferiority of agriculture to industry was quite clear.[9] But, historically, industrialization was facilitated by an appropriate growth in the agricultural sector in the U.K. and Western Europe, U.S.A. and Japan. In these countries, agriculture supplied not only food and agricultural raw materials, but also the market for industrial goods as well as the required labor force and savings.

A good number of developing countries did pursue the path of fast industrialization. A brief overall picture of these countries may be summarized as follows: 1) Varying levels of industrialization took place; but vast majority of population still dependson traditional agriculture for its survival. 2) In most cases the industrial technology adopted was capital-intensive type perfected in developed countries in the face of labor shortage. 3) The rural-urban income disparity increased considerably and this led to large scale migration from countryside to cities even when unemployment and underemployment in urban areas were high. 4) Public health measures, especially control of communicable diseases led to a substantial reduction in mortality, fertility remaining more or less unchanged, causing an accelerated population growth, which resulted in substantially reduced per capita growth compared to the growth of national income.

The above scenario characterizes most of the developing economies today. The classical dual nature of these economies has not changed. The presumed linkage effects of industrialization on the rural sector of the economy did not materialize. The economic impacts of modern industrial activities of the urban centres have been minimal on the adjoining rural populations. In most cases they continue to cultivate their farms in the age-old fashion within the old institutional framework.

As the largest economic sector in most developing countries, agriculture inevitably plays a key role in their development, either as an obstacle to be overcome or as a foundation upon which to build. But unfortunately in most cases it was the former role that was stressed.

But, the industrial fundamentalism of the fifties and sixties is losing its significance to policy makers as evidenced from statements like that of President Nyereye of Tanzania[10]: "Tanzania will continue to have predominantly rural economy for a long time to come. As it is in rural areas that people live and work, it is in the rural areas that life must be improved. It would be grossly unrealistic to imagine that in the near future more than a small proportion of our people will live in towns and work in modern enterprises".

Also, the view that growth without distributional consideration should not be pushed too hard has become prevalent.[11] Development policies cannot treat the well-being of most of the population as an instrument to achieve growth rather than an objective of policy.

It should be stressed that the foregoing discussion does not imply that industries are to be neglected. Indeed, some of the most chronic difficulties of agriculture can be effectively resolved only by developments in the non-agricultural sectors of the economy. Our only implication is that agriculture is too important to be left to develop by itself while national planning concentrates on industrialization.

I.4. Peasant Decision Making

A vast literature has been accumulated in the process of economists' attempt at explaining the behavior of poor farmers in traditional societies. The fundamental question is whether the standard theory of economic behavior and organization could be of much help in analyzing the peasant decision making.

Agriculture in developed countries is generally considered a typical example of neo-classical perfect competition. How far is this true in underdeveloped, climatically uncertain, subsistance farming? If the peasant is an optimiser in the above sense, he must allocate productive factors so as to equate the marginal value-product of each factor in every use. But, as was discussed in section I.2, several practices and institutions in peasant societies apparently do not conform to perfect competition.

Further, several economists and scholars of other disciplines put forward various hypotheses, based on casual empiricism, to the effect that peasants do not respond to economic incentives; but their behavior is conditioned by institutional and cultural factors. Thus, for example, the 'mythical' backward-bending supply curve of labor based on the hypothesis of 'target income'[12] implies that wage incentives have the perverse effect of decreasing labor supply and output. Of course, backward-bending supply curve of labor is a defensible concept on theoretical grounds. But that is beside the point. The main issue is that if such were the actual situation in peasant economies, ordinary economic analysis can do little to enlighten development planners and policy makers.

I.4.1. Efficiency of Peasant Farming

A significant thesis, now of classic importance, was put forward by Theodore Schultz [1964]. Defining allocative efficiency in terms of profit maximization, Schultz hypothesized that there are comparatively few significant inefficiencies in the allocation of the factors of production in traditional agriculture. The basic premise of his thesis is that there is nothing in the peasant economies which cannot be fitted into the neo-classical framework.

Schultz built the foundations of his 'Transforming Traditional Agriculture' primarily on two empirical studies, one by Sol Tax [1953] in a Guatemalan village and another by David Hopper [1965] in an Indian village. The overall conclusion from both these studies was that peasants are efficient but poor. Schultz's policy conclusion is that no appreciable increase in agricultural production is to be had by reallocating the factors at the disposal of farmers who are bound by traditional agriculture.

But these conclusions follow only under the assumption of perfect competition. In particular, a perfect market in factors and products must exist, and each farmer must be able to predict with reasonable confidence, the outcome of each array of production, consumption and sale decisions at his disposal. Of course, all these were explicitly or implicitly assumed in both Tax and Hopper studies.[13] Schultz further argues that peasants, though efficient, are poor because they live and operate in a static environment. Farmers, on their own, are incapable of getting out of this secular stagnation. They have no incentives to work harder or save and invest more, because in this static environment marginal products of all factors are negligible.

As Michael Lipton [1968, p. 329] puts it, this is a doctrine of revolutionary pessimism. There is no scope for small changes and improvements. Either a social revolution of immense dimensions should take place or a big-push through huge public investments should take place. Schultz recommended the latter and indeed, a number of developing countries tried to practice this.[14]

We do not attempt a categorical attack on either the arguments or the conclusions of Schultz. However, we have some doubts about his basic assumptions of static environment and the suitability of profit maximization as the decision criterion. The first question is whether the kind of static environment visualized by Schultz is that common in peasant economies. One important aspect of traditional agriculture is its diversity in farming techniques, practices and institutions. Even in the same village different farmers may follow entirely different farm practices.[15] Also, varying levels of development efforts are changing the static set-up. Moreover, when population-farmland ratio doubles in a generation, any static relation simply cannot exist in the rural environment. Last, but not least, the environment is perpetually disturbed by the hazards of nature in the least predictable manner. In an important empirical study, Daram Narain [1965] established that the most important explanatory factor for the variation in cropped area under wheat and rice in India was rainfall, though the corresponding factor for cash crops was market price.

The other important issue is regarding farmer's optimising criterion. Even if one considers rainfall as the only uncertain factor, it is clear that there is no way of predicting it reasonably correctly. In general, the smaller the average rainfall, the greater is the coefficient of variability.[16] That is, the greater the impact of future rainfall upon optimal policy, the smaller is knowledge of that rainfall, and the likelier the marginal value-product equalization to lead to disaster. Even if one assumes that the farmer is an expected profit maximiser, the logical dilemma remains. Expected marginal value-product equalization is necessarily a long-run sequential decision process. Compared with a lower mean, lower variance strategy, this substantially reduces its practitioner's prospects of surviving to complete the sequence. Therefore, the poorer the farmer, the stronger will be his incentive to reject this criterion. Arguments about optimal policies based on false analogies with the rich and risk-cushioned farmers of the west may not be relevant in the case of subsistence farmers of peasant economies. A bad year or two, in an optimal policy sequence will not prevent the western farmer from retaining land and other assets sufficient to follow through the sequence, but they may ruin a poor farmer in India. His first duty to his family is to prevent such ruin.

A well-off Prairie farmer may safely prefer a 50-50 chance to $50000 or $100000 to a certainty of $70000 per year. An Indian farmer, offered a chance of Rs X or Rs 1000 as against a certainty of Rs 700 a year with which he barely feeds his family, cannot set X far below Rs 700.[17]

I.4.2. Green Revolution

Soon after Schultz put forward his thesis, many developing countries got opportunity to attempt transforming traditional agriculture through 'green revolution'.[18] Countries which were pursuing industrialization at the cost of agriculture turned to green revolution as an opportunity to modernize the agricultural sector. But most of the enthusiasm of the mid-sixties was dampened by early seventies when it was generally observed that even with wide publicity, massive public investment and substantial subsidization, the small farmers did not accept the 'miracle' seeds and accompanying technology.[19]

Once more, skepticism was raised by agronomists, development planners and other field-experts.[20] But even at the peak of green revolution, some economists were expressing caution. For example, Wharton [1969, p. 466] warned: Attempts at change, especially those which come into direct conflict with the fundamental goals of security and survival, must take into account the degree of risk and uncertainty associated with change. Risk is not the only factor which retards development, but its elimination or reduction should prove a major stimulus for technological innovation and the modernization of subsistence agriculture. Similarly Barker [1969, p. 1] cautioned: The lower expenditure for cash inputs may have reflected the inability to obtain credit, but appears to have been more directly concerned with the higher risk involved on farms with inadequate water control. Much of the rice growing area of Asia is rain-fed. Farmers in these areas cannot afford the risk of applying high levels of cash inputs needed to achieve the potential benefits from new varieties of seeds.

There is general agreement that green revolution has been successful only where the effects of natural hazards are minimal and that too among comparatively rich farmers.[21] It may be that in the same area, profit maximizing and risk-avoiding farmers operate side-by-side without substantial competition. One could argue that profit maximization is a special case of the more general behavior pattern of utility maximization. Poor farmers, while maximizing utility, place emphasis on survival when faced with uncertainty. It is common knowledge that innovative farming is riskier than traditional farming and the investment requirements are much higher in the former compared to the latter. For example, an IRRI study[22] shows that for a Filipino rice farmer, traditional farming requires $20 per hectare whereas IR-8 variety rice-cultivation requires $220 per hectare.

The greater risk-bearing capacity of the big farmers puts them in a more advantageous position to exploit the new opportunities. Earlier, the inequalities of income arising out of the unequal distribution of land were to some extent reduced by productivity differences between the small and large farms, in favor of the small ones.[23] But, after the setting in of the green revolution, this relationship has undergone a drastic change. The inverse relationship has now yielded place to a positive relationship.[24] It implies that as farm size increases, income increases more than proportionately. This sufficiently establishes the fact that in areas where green revolution was successful, the income gap between the small and large farms has widened.[25]

Another aspect of the green revolution is large-scale mechanization on the part of bigger farmers and the associated labor replacement which aggravates rural-urban migration problem. This issue will be dealt with in some detail, subsequently.

I.4.3 Decision Criterion

If profit maximization is unacceptable as a model for peasant behavior under uncertainty, what alternatives should be tried?[26] Expected utility maximization is the most widely used criterion in such contexts.

But recently Roumasset [1976] argued that this criterion ignores decision costs altogether. He contends that most decision problems under uncertainty are so complex and decision costs so important that expected utility maximization is not a reliable guide to behavior. He devises two rules-of-thumb, based on lexicographic safety-first principles and applies them to data on fertilizer-application of Filipino rice farmers. His major conclusion is that risk-neutrality is a better behavioral assumption than risk-aversion to predict the behavior of these farmers. Further, he argues that the goals of expected profit maximization and safety are not in conflict for the fertilizer-application decision of Filipino rice farmers and generalizes that this should be the case with all aspects of agricultural innovation.

We have some reservations about Roumasset's methodology and conclusions. First, the basis for discarding expected utility criterion is rather weak. The received theory of uncertainty[27] firmly supports the soundness of this criterion. It is too hasty to conclude that a rule-of-thumb is to be preferred to a well-established criterion on the argument that the former is cheaper as a decision rule compared to the latter.

As for the findings, at the most one can say that a sample of 67 comfortable Filipino rice farmers did not reveal any significant risk-aversion as measured by a rule-of-thumb based on safety-principles as far as their fertilizer application decision was concerned. Though the author uses the general heading of 'low-income farmers' all indications[28] suggest that he was not considering the behavior of poor peasant farmers and as such his findings do not contradict the observations of Schultz, Lipton, Wharton, Barker and others.

Recent fertility surveys in connection with family planning programs in different developing countries have given a clear indication regarding the risk averse nature of poor people's reproductive behavior.[29] In many instances a large family is the best security for old age.

As explained earlier, many other institutions and practices peculiar to peasant societies are essentially insurance surrogates. The poor, by the very fact of their poverty, have little margin for error. The very precariousness of their existence habituates them to be cautious. They may be illiterate. But they are seldom foolhardy. To survive at all, they are forced to be shrewd and cautious.

Summing up, we have strong reasons to believe that uncertainty due to natural hazards is an important factor affecting the decision process of peasant farmers in traditional agriculture. As such, simple profit maximization or utility maximization will have little operational significance in explaining their decisions. Further, risk-aversion as a behavior mode appears to be reasonable, especially among poor peasants. Besides, expected profit maximization is a special case of expected utility maximization. So, for lack of good evidence, a general methodology is a better guide to behavior than its special case.

We admit that attitudes to risk as measured by risk-aversion will vary both among farmers and, for one farmer, among different levels of expected income. In the subsequent analysis we make extensive use of the Arrow-Pratt risk aversion functions[30] and their properties.

I.5. Scope of the Present Study

It may be already apparent from the thrust of our arguments in the earlier sections that the basic focus of our study is on the role of uncertainty in traditional agriculture. In order to concentrate on the behavioral implications of uncertainty on production and consumption decisions, and to project their relevance for public policies, we make some simplifying assumptions. First, we assume away the role of prices and price uncertainty by restricting to real analysis. By this we do not imply that demand and supply management through price policies are irrelevant in traditional economies. At least in some developing countries, price policies are effectively implemented.[31] Indeed, this is one of our reasons for implicitly assuming the absence of compensatory price variations to output changes. Also, in some countries, non-monetized subsistence farming may be a significant segment of the economy.

Second, we do not explicitly take into account, the role of fixed capital in traditional agriculture and as such we are not concerned with saving and investment also. Though apparently this seems to be a limitation, some reflection may justify this. Most of the capital associated with peasant farming are simple conventional tools, structures, land improvements, simple irrigation devices and farm animals. It may be reasonable to assume that these are proportional to the farm size and as such are taken care of by our definition of the factor 'land'. Further, we treat 'fertilizer' as a proxy for all variable factors other than labor.

Structural and institutional imperfections in factor and product markets in traditional economies are familiar themes in development economics. Indeed, a number of theories in the literature have their bases on one or more such imperfections.[32] In our analysis, we implicitly assume away such imperfections. Our main argument is that most of these imperfections are direct or indirect manifestations of decision making under uncertainty. And one of our principal endeavors is to identify the most effective public policy tools to eliminate or reduce such imperfections.

As we have explained elsewhere, agriculture is the largest economic sector in most developing countries. But the share of peasant farming and the role of uncertainty arising from natural hazards may vary substantially among these countries. Our analysis is developed mainly in the context of south and south east Asia, especially India, where natural hazards of farming are very significant, farm land is scarce, population is growing fast, average farm size is very small and where economic development is attempted without radical social revolutions. Availability of literature and familiarity with the institutional set-up may be considered reasonable excuses for this restriction.

However, the present analysis should be equally relevant to, say coffee cultivation in Brazil[33] and subsistence farming in Shahel region of Africa. Also, with some modifications, our analysis can be used to explain the behavior of fishermen, along the entire coast of mainland-Asia, whose technology of fishing may be as traditional as that of peasant's farming and whose dependence on nature's goodwill even greater.

In chapter two we introduce a simple decision model of a typical peasant farmer, facing output uncertainty. After deriving the implications of uncertainty on his factor use, we investigate the effects of various public policies including fiscal policies and institutional changes on his behavior. This investigation is done essentially as comparative static analysis and by relating certain parametric changes to relevant policies. Wherever possible, we compare our results with the standard policy assumptions, some of which are based on deterministic models and others based on political considerations and administrative rules-of-thumb. In a number of cases, we argue that optimal policies are different from the existing ones. Further, we generalize the model to include input uncertainty also. Instead of assuming that inputs are committed before farming and hence are not subject to uncertainty with the weather, it may be more realistic to assume that the farmer adjusts his decisions regarding the application of inputs as the weather uncertainty unfolds itself through planting, weeding and harvesting seasons. Moreover, there may be other random factors affecting the flow of different inputs. With this realistic generalization, which substantially complicates the model, the above analysis is repeated.

Chapter three deals with the specific problem of rural-urban migration. For this, we introduce a modified version of our model of chapter two. The standard theory[34] on rural-urban migration in traditional economies treats the wage income as uncertain, assuming that the farm income is certain. We are looking at the problem from the opposite side, that is, stressing the role of uncertainty in farm income. Expressed in the standard jargon, we concentrate on the 'rural push' rather than the 'urban-pull'. Within this framework, we analyse the peasant household behavior as regards to migration. The effects of a number of public policies including investment in agriculture, land reform, and income tax, on migration are analysed.

In the earlier chapters, we were concerned with the implications of uncertainty on peasant decisions and the impacts of certain public policies on them. Some of these policies have direct bearing on elimination or reduction of the impact of uncertainty. But elimination or reduction of agricultural uncertainty may not be always feasible or desirable. In such cases, as Arrow [1971, p. 143] argued, the best solution would be to transfer the risk to an agency best able to bear this risk. The social and private benefits of such risk-transfer may well exceed the costs. This is quite true in the case of much of the traditional agriculture, most of which heavily depends on the vagaries of the weather.

Taking these facts into account, we devote chapters four and five to develop a theory of crop insurance. In chapter four we develop a theory of crop insurance within a general equilibrium framework. We begin by clarifying certain conceptual and analytical issues which demonstrate the need for a separate theoretic analysis of crop insurance. Then, we provide certain theoretical justifications for the non-existence of competitive crop insurance markets. And finally, a theoretical model of public crop insurance is developed and its properties analysed. In chapter five, we discuss the role of insurance in general, and crop insurance in particular. Also, the distinct problems of crop insurance are presented and the traditional insurance surrogate institutions and practices discussed. Further, a viable crop insurance program specifically, in the context of India, is developed.

The final chapter attempts a brief appraisal of our findings and their relevance to practicing development planners and policy makers. Also, the limitations of our study and the scope for further theoretical and empirical investigations are indicated.

An appendix describing, in simple terms, some of the tools in the analysis of behavior under uncertainty is given at the end of the thesis.

Footnotes

1. Two aspects of the Hindu and Buddhist belief in 'Karma' are alluded here viz. 1) the results of one's actions are influenced by one's destiny and 2) the destiny itself could be influenced by one's actions.

2. As developed mainly by Arrow [1965] and Pratt [1964]. The relevant parts of this theory are presented in simple terms in an Appendix, at the end of the thesis.

3. For example, the Indian Agricultural Policy in the mid-sixties as noted by Lipton [1968, p. 348].

4. Some of the important studies are, Frankel [1971, especially chapter 7], Bardhan [1974] and Saini [1976].

5. For definition and other details, see section A.3 of Appendix.

6. For details, see Lipton [1968, pp. 340-46].

7. Nurkse [1953] and Lewis [1955] are two good examples.

8. Balanced growth models, unbalanced growth models and labor surplus models are some important examples.

9. For example Hirschman [1958, pp. 109-110] states "Agriculture certainty stands convicted on the count of its lack of direct stimulus to the setting up of new activities through linkage effects: the superiority of manufacturing in this respect is crushing."

10. This statement is reproduced in Bird [1974, p. 20] from Development Digest, Vol. 8, No. 4, October 1970.

11. See for example, Frankel [1971, chapter 7] and Bird [1974, chapter 2].

12. For a good exposition of this hypothesis and its empirical rejection, see Dean [1966].

13. For details, see Lipton [Ibid, pp. 327-32].

14. We allude mainly to the increased attention to agricultural transformation in the wake of 'green revolution'. For details, see for example, S. Sen [1975].

15. A typical case of an Indian village is described in Lipton [Ibid, pp. 339-42].

16. For empirical support, see Naqvi [1949].

17. A similar example is discussed in more detail in Lipton [1968].

18. This mainly refers to the introduction of high yielding varieties of wheat and rice and the accompanying techniques and inputs on a mass scale and the resulting abundant agricultural production.

19. For empirical support, see, for example Frankel [1971].

20. For a variety of such views of an assorted set of experts, see S. Sen [1975, pp. 3-5].

21. See Bardhan [Ibid], Saini [Ibid] and Frankel [Ibid].

22. International Rice Research Institute (IRRI) study result as reported in Wharton [1969, p. 470].

23. This is empirically and theoretically supported by Bardhan [1973, 1974b], H. Rao [1971] and Saini [1976].

24. For empirical support, see Barhan [1974b], H. Rao [1971], Saini [1976] and Wills [1972].

25. The associated socio-economic and political problems are lucidly discussed by Frankel [1971] after an on-the-spot study of five districts in India, which were covered by the Intensive Agricultural Development Program of the Government of India and where green revolution was most successful.

26. We do not explicitly consider Mean-Variance analysis, as it is a special case of expected utility maximization where 1) the yield distributions are normal or 2) the utility function is quadratic.

27. As in Arrow [1971] for example.

28. For example: "Tenants are the middle-class of the Philippine agriculture. Their essential duty is management" Roumasset [1976, p. 97]. "Farmers typically live well above subsistence. Their daily fare usually includes meat and vegetables, their houses are usually permanent structures, they often have non-farm income and they own farm and non-farm capital goods" Roumasset [Ibid, p. 161]. "Since none of the farmers considered starvation a feasible outcome, the disaster level was defined as that level of income per hectare that the farmer needs to avoid

selling major non-liquid assets" Roumasset [Ibid, pp. 216-17].

29. See for example, McNamara [1977].

30. These functions and their properties are presented in simple terms in an Appendix at the end of the thesis.

31. The significance and effectiveness of agricultural pricing policies in India are given in Govt. of India [1974].

32. Examples are the various dual economy models and surplus labor models.

33. As against the production of 28 million bags in 1975, the estimated output of Coffee in Brazil in 1976 was 9 million bags [Source: New York Times report, January 11, 1977].

34. See for example, Harris and Todaro [1970].

CHAPTER II

FACTOR USE AND FARM PRODUCTIVITY UNDER UNCERTAINTY

II.1. Introduction

In the past few years a fairly extensive literature has developed that examines the economic behavior of modern competitive firms facing uncertain environment.[1] Agricultural production in peasant or traditional economies is notorious for its dependence on the vagaries of weather. To date, however, only a few attempts have been made[2] to rigorously analyse the behavior of peasants in the face of output uncertainty. In addition, it should be noted that development programs and public policies in these economies are based mostly on the conventional wisdom derived from deterministic microeconomic theory. But, as was discussed in chapter I, deterministic models are unable to explain many features of peasant behavior. Apathy towards new techniques and inputs, bonded labor, share-cropping tenancy, a single holding divided into several tiny patches, payment of interest on loan in kind at a higher rate than in cash and many other conventional practices and institutions remain unexplained or rest as issues of theoretical controversy.

The purpose of this chapter is to develop a model of peasant behavior under uncertainty and to analyse the implications of various public policies in a typical peasant economy. Wherever possible, an attempt is made to compare the results from the stochastic analysis with the usual policy prescriptions based on deterministic models. Further, we attempt to show that if peasants are considered as essentially operating under conditions of uncertainty, most of the apparently irrational behavior can be given economic rationalization.

Given the introduction, the rest of the chapter proceeds as follows. In Section 2 the basic model with uncertainty in output is introduced and some interesting general results are derived. Section 3 is devoted to comparative static analysis. Here we relate a number of parametric changes to various public policies and derive their implications on peasant behavior. In Section 4 the basic model is extended to include both output and input uncertainty simultaneously. In the final section some concluding remarks are made along with suggestions for possible extensions of the present analysis.

II.2. A Simple Model and Some Basic Results

Consider a farmer who owns 'H' hectares of land. He uses two variable inputs,[3] labour (L) and fertilizer (F) on his land to produce a homogeneous output (Q). In addition, it is assumed that due to uncertain weather conditions the output depends multiplicatively[4] upon a non-negative random variable (r), the distribution of which is independent of the inputs. Total yield is given by

$$Q = Hf(L, F)r \tag{1}$$

where f is the production function and L and F are inputs used per hectare. It is assumed that the marginal products of inputs are positive and that the production function is concave. The nature of the distribution of r is characterised by its density function dF(r). The first two moments are

$$E(r) = 1 \text{ and } V(r) = \sigma^2 < \infty \tag{2}$$

Further $\frac{\partial Q}{\partial r} > 0$, that is r contributes to output in the same way as non-random inputs. The farmer's net income (measured in units of output) is given by

$$Y = Q + w(\bar{L}-HL) - pHF \tag{3}$$

where w is the prevailing wage rate, p is the market price of fertilizer and $\bar{L}$ is the total labour the farmer himself supplies. It is clear that he sells his surplus labour at the wage rate w if $\bar{L} > HL$ or buys his excess labor requirements at the same wage if $\bar{L} < HL$ where HL is his labour demand.[5] The advantage of this formulation is that we can separately analyse the cases of farmers who are net suppliers of labor and demanders of labor. Usually smaller farmers are the former type and larger ones the latter respectively.

The farmer is assumed to maximise his expected utility of income by the choice of the amounts of labor and fertilizer. Further, we assume that his attitude towards risk can be summarized by a Von Neumann-Morgenstern utility function.[6] Thus the mathematical formulation of the farmer's problem is

$$\max_{[L,F]} E[U\{Hf(L,F)r + w(\bar{L}-HL) - pHF\}]$$

where E is the expectation operator. Assuming that differentiation of expected values is permitted[7], the first order conditions for an interior extremum are

$$H\ E[U'(Y)\{f_1\ r-w\}] = 0 \quad (4)$$

$$H\ E[U'(Y)\{f_2\ r-p\}] = 0 \quad (5)$$

where f_1 and f_2 denote partial derivatives of f(L,F) with respect to L and F respectively. Hereafter, for convenience we write U, U' and U" for U(Y), U'(Y) and U"(Y) respectively. The second order conditions require that for a maximum:

$$A_1 = \frac{\partial^2 E[U]}{\partial L^2} = E[H\ U''\{f_1 r - w\}^2 + U' f_{11}\ r] < 0 \quad . \tag{6}$$

and

$$D = \begin{vmatrix} A_1 & B_1 \\ B_1 & A_2 \end{vmatrix} > 0 \tag{7}$$

where

$$A_2 = \frac{\partial^2 E[U]}{\partial F^2} = E[H\ U''\{f_2 r - p\}^2 + U' f_{22} r] \tag{8}$$

and

$$B_1 = \frac{\partial^2 E[U]}{\partial L \partial F} = E[H\ U''\{f_1 r - w\}\{f_2 r - p\} + U' f_{12} r] \tag{9}$$

Also, (7) implies that[8] $A_2 < 0$.

If the farmer is risk-averse, that is if $U'' < 0$, it can be shown that[9] strict concavity of the production function is sufficient but not necessary for the second order conditions to be satisfied. In the subsequent analysis it is assumed that the second order conditions are satisfied.

Since f_1 and f_2 are non-random, it follows from (4) and (5) that

$$\frac{f_1}{f_2} = \frac{w}{p} \tag{10}$$

This is the familiar cost minimisation condition. It implies that even when the output is uncertain, the farmer equates the marginal rate of technical substitution between factors and the factor price ratio at the optimum expected output. This is especially interesting, because immediately below we show that an optimising risk-averse farmer expects to produce an output at which the value of expected marginal product of each input exceeds the given input price. That is, his optimum expected output is such that the value of marginal product exceeds the marginal cost though the input-mix at that level of expected output is cost-efficient.

Equation (4) can be written as

$$E[U'f_1 r] = E[U'w] \tag{4'}$$

Subtracting $E[U'f_1]$ from both sides of (4'), we get

$$E[U'f_1(r-1)] = E[U'(w-f_1)] \tag{11}$$

Taking expectations on both sides of (3) yields

$$E(Y) = Hf + w(\bar{L}-HL) - pHF$$

Using this result, Y can be rewritten as

$$Y = E(Y) + Hf(r-1)$$

If the farmer is risk-averse so that $U'' < 0$, then

$$U'(Y) \leqq U'[E(Y)]$$

for $r \geqq 1$. Multiplying both sides by $f_1(r-1)$, we get

$$U'(Y)\ f_1(r-1) \leqq U'[E(Y)]\ f_1(r-1)$$

for all r.[10] Taking expectations on both sides,

$$E[U'(Y)\ f_1(r-1)] \leqq 0 \tag{12}$$

as $U'[E(Y)]f_1$ is non-random and $E(r) = 1$. Using (12) in (11), we get

$$E[U'(w - f_1)] \leqq 0$$

which implies, since U' is always positive, that

$$w \leqq f_1$$

It easily follows from (10) that

$$p \leqq f_2$$

also. Together with the concavity of the production function, these results imply that under output uncertainty the optimal input use is lower than that in the certainty case. That is, if the farmer is risk-averse, then the effect of uncertainty is to reduce use of each variable input. It easily follows that the expected optimum output under uncertainty will also be lower than that in the certainty case. It may be mentioned in this connection that Hazell and Scandizzo,[11] in a mean-variance framework and using labor as the only variable factor, arrived at similar results for a peasant farmer operating under output uncertainty. Also, recently, Wiens [1977, p. 50-55] reached similar conclusions, using expected utility approach, for farmers facing uncertainty of returns from the sale or rental of family assets, such as land, labor and liquid capital in the factor markets.

An intuitive explanation of this result is as follows. Assume r = 0 with probability $\frac{1}{2}$ and r = 2 with probability $\frac{1}{2}$. Therefore E(r) = 1. If r = 0 is the realization, then the farmer suffers a loss of (WLH + pFH). If he uses smaller amounts of inputs his maximum losses also will be smaller. Thus we can think of the farmer as reducing the riskiness of the situation by shifting part of the risk to the inputs and thereby using less of them. Note, however, that the first order conditions will hold in all cases.

Our result has an analogy with the standard result in Arrow's Portfolio Choice Model involving a risky asset and a safe asset. In our model the role of a secure asset is that of wage labor at a secure wage and the role of risky asset is that of farming. The farmer, in part decides on the optimal allocation of his endowment of labor between these two activities.

Finally, if we assume that the farmer is risk-neutral, that is if U" = 0 and hence U' a constant, from (4') it immediately follows that $f_1 = w$, as E(r) = 1. Similarly we can see that $f_2 = p$. That is, a risk-neutral farmer operating under conditions of output uncertainty behaves just like a farmer operating under conditions of certainty as far as his input decisions are concerned.

Though the assumption of risk-aversion is reasonable for small farmers, risk-neutrality may be a reasonable behavioral hypothesis for wealthy farmers.[12] Wealthy farmers might have even displayed risk-preference when they adopted high-yielding varieties of seeds in the earlier stages of green revolution.

II.3. Comparative Statics - Effects of Public Policies

II.3.1. Farmer Response to Marginal Impacts on Uncertainty

Here we consider the effects of marginal changes in riskiness of farming and the mean of the distribution of random variable on the behavior of the farmer. Adopting the Rothschild and Stiglitz's[13] definition of change in risk, we define a change in risk as a change in variance without affecting the mean of the distribution. Define $r^* = \delta r+\theta$, where δ and θ are two shift parameters with initial values 1 and 0 respectively. The variance of r^* is given by $V(r^*) = \delta^2 V(r) = \delta^2\sigma^2$, by (2). In order to restore the mean, we should have $dE(r^*) = dE(\delta r+\theta) = 0$, which implies

$$\frac{d\theta}{d\delta} = -E(r) = -1 \tag{13}$$

by (2). Replacing r by r* in (3), the first order conditions become

$$E[U'\{f_1(\delta r+\theta) - w\}] = 0$$

$$E[U'\{f_2(\delta r+\theta) - p\}] = 0$$

Differentiating these equations implicitly with respect to δ and evaluating the results at $\delta = 1$ and $\theta = 0$, on simplification we get

$$A_1 \frac{\partial L}{\partial \delta} + B_1 \frac{\partial F}{\partial \delta} = M_1 \tag{14}$$

$$B_1 \frac{\partial L}{\partial \delta} + A_2 \frac{\partial F}{\partial \delta} = M_2 \tag{15}$$

where A_1, A_2 and B_1 are as defined in (6), (7) and (9) respectively and

$$M_1 = - HE[U''f(r-1)(f_1r-w)] - E[U'f_1(r-1)]$$

$$M_2 = - HE[U''f(r-1)(f_2r-p)] - E[U'f_2(r-1)]$$

Using (10) we can see that $M_1 = \frac{f_1}{f_2} M_2$. Solving (14) and (15) simultaneously and substituting the expressions for A_1, A_2 and B_1 we get

$$\frac{\partial L}{\partial \delta} = M_2 \frac{E[U'r](f_1 f_{22} - f_2 f_{12})}{D f_2} \tag{16}$$

$$\frac{\partial F}{\partial \delta} = M_2 \frac{E[U'r](f_2 f_{11} - f_1 f_{12})}{D f_2} \tag{17}$$

Since U' and r are non-negative, E[U'r] is positive. Also D is positive by (7). Concavity of f implies that $f_{ii} < 0$ (i = 1, 2). Further, if we make the reasonable assumption of complementarity of inputs,[14] that is $f_{12} > 0$, then the signs of (16) and (17) will be opposite to that of M_2. Now

$$M_2 = - HfE[U''\{f_2r-p\}\{(r-\frac{p}{f_2}) + (\frac{p}{f_2} - 1\}] - E[U'f_2(r-1)]$$

$$= - HfE[U'' \frac{\{f_{22}-p\}^2}{f_2}] - HfE[U''\{f_2r-p\}](\frac{p}{f_2} - 1)$$

$$- E[U'f_2(r-1)]$$

If the farmer is risk-averse, the first expectation term is obviously negative; the last expectation term can be shown to be negative by some algebra exactly similar to that used to derive (12) earlier.

We can further show that if the farmer's absolute risk-aversion is non-increasing,[15] that is if $R'_A(Y) \leq 0$ where $R_A(Y) = - \frac{U''(Y)}{U'(Y)}$, then the second expectation term is positive.[16] Let Y* be the income when $f_2r-p = 0$. Therefore $R_A(Y) \leq R_A(Y^*)$ for $f_2r-p \geq 0$. That is $- \frac{U''(Y)}{U'(Y)} \leq R_A(Y^*)$ for $f_2r-p \geq 0$. Also we know that $- U'(Y)(f_2r-p) \leq 0$ for $(f_2r-p) \geq 0$. Therefore $U''(Y)(f_2r-p) \geq - R_A(Y^*)U'(Y)(f_2r-p)$ for $(f_2r-p) \gtrless 0$. Taking expectations on both sides, $E[U''(Y)(f_2r-p)] \geq - R_A(Y^*)$ $E[U'(Y)(f_2r-p)] = 0$ by first order condition. In section 2 we have already seen that $(\frac{p}{f_2} - 1)$ is negative. So we can conclude that M_2 is positive. From (16) and (17) it follows that

$$\frac{\partial L}{\partial \delta} < 0 \text{ and } \frac{\partial F}{\partial \delta} < 0.$$

That is, if the farmer's behavior is characterised by non-increasing absolute risk-aversion, then a marginal decrease (increase) in risk will unambiguously increase (decrease) the use of all variable inputs. But from the way the sign of M_2 depends on the three expectation terms it is clear that non-increasing absolute risk-aversion is sufficient but not necessary for our conclusion.

To determine the effect of a marginal change in risk on the expected output, consider

$$E(Q) = HfE(r) = Hf$$

Therefore

$$\frac{\partial E(Q)}{\partial \delta} = H[f_1\frac{\partial L}{\partial \delta} + f_2\frac{\partial F}{\partial \delta}] < 0$$

as $\frac{\partial L}{\partial \delta} < 0$ and $\frac{\partial F}{\partial \delta} < 0$. That is, a marginal decrease (increase) in the risk of farming will increase (decrease) the expected output as it increases (decreases) the use of all variable inputs.

Similar results were obtained in the theory of firm under price uncertainty by Sandmo [1971] in the context of a short-run model and by Batra and Ullah [1974] in the context of a long-run model. Also, it may be mentioned that in a competitive framework the effects of uncertainty in output of the product and product price are very similar.

We can express the above conceptual experiment somewhat differently as follows. Assume that there are two farmers with identical production functions, utility functions, factor endowments and facing the same market. They differ only in their perception of the riskiness of farming, that is, their subjective probability distributions have different variances, though the means are identical. The experiment we presented is an example of how they may use different quantities of L and F. This proposition can be empirically verified if one can find data for farmers who are reasonably homogenous except for their risk-perception.

Within the limitations of the present model we may conclude that any public policies directed at reducing the natural risk of farming will induce the farmer to employ more of every variable input on his farm of given size, which in turn will increase the expected output. Examples of such policies are provision of improved weather forecasting service, better irrigation facilities, flood control and pest resistant seed varieties.

Next we consider the effects of a shift in the distribution of the random variable without affecting risk, that is, the effects of a 'variance preserving change' in the mean of the distribution. Following Sandmo [1971, p. 69], define $r^* = r + \theta$, where θ is a shift parameter with zero as initial value. Replacing r by r^* in (3), the first order conditions become

$$E[U'\{f_1(r + \theta) - w\}] = 0$$

$$E[U'\{f_2(r + \theta) - p\}] = 0$$

Implicitly differentiating these equations with respect to θ and evaluating the results at $\theta = 0$,

$$A_1 \frac{\partial L}{\partial \theta} + B_1 \frac{\partial F}{\partial \theta} = - E[U''f(f_1r-w) + U'f_1] \quad (18)$$

$$B_1 \frac{\partial L}{\partial \theta} + A_2 \frac{\partial F}{\partial \theta} = - E[U''f(f_2r-p) + U'f_2] \quad (19)$$

Simultaneously solving (18) and (19), substituting the expressions for A_1, A_2 and B_1 and simplifying the results using (10), we get

$$\frac{\partial L}{\partial \theta} = E(U'r)[E(U') + \frac{f}{f_2} E\{U''(f_2r-p)\}](f_2f_{12} - f_1f_{22}) \quad (20)$$

$$\frac{\partial F}{\partial \theta} = E(U'r)[E(U') + \frac{f}{f_2} E\{U''(f_1r-w)\}](f_1f_{12} - f_2f_{11}) \quad (21)$$

Earlier in this section we have shown that if the farmer has non-increasing absolute risk-aversion, then $E\{U''(f_2r-p)\}$ is positive. Under the same assumption $E\{U''(f_1r-w)\}$ also can be shown to be positive. If we further assume that $f_{12} > 0$, then it is clear that $\frac{\partial L}{\partial \theta} > 0$ and $\frac{\partial F}{\partial \theta} > 0$. In words, a rise (fall) in the expected value of the random variable will induce the farmer to apply more (less) of each variable input. It easily follows that under the same set of assumptions $\frac{\partial E(Q)}{\partial \theta} > 0$ also. If one treats technological progress, use of high yielding varieties of seeds and more fertile land as equivalent to rightward shift of r without changing its variance, one can conclude that these will lead to increased use of all variable inputs and hence higher expected output.

Also one can express the above conceptual experiment somewhat differently by considering two farmers who are identical in every respect except that this time their subjective probability distributions have different means though variances are the same. The experiment we presented is an example of how they may use different quantities of labor and fertilizer leading to different levels of expected outputs.

The results presented in this section may appear intuitively clear; but note that they follow only under certain assumptions, though reasonable, regarding the farmer's risk-behavior. Under alternate assumptions we can reverse these results. For example, if the farmer is risk-neutral, risk-reducing public policies will have no effect on his behavior. A limitation of the present analysis is that we cannot handle an arbitrary situation where change in both the variance and the mean of the distribution of the random variable occurs. Presumably many relevant public policies are of this type.

II.3.2. Production Effects of Factor Price Policies

First, consider a change in the wage rate, the price of fertilizer remaining constant. Implicit differentiation of (4) and (5) with respect to w yields

$$A_1 \frac{\partial L}{\partial w} + B_1 \frac{\partial F}{\partial w} = E(U') - (\bar{L} - HL)E[U''(f_1 r-w)] \qquad (22)$$

$$B_1 \frac{\partial L}{\partial w} + A_2 \frac{\partial F}{\partial w} = - (\bar{L} - HL)E[U''(f_2 r-p)] \qquad (23)$$

Solving (22) and (23) simultaneously

$$\frac{\partial L}{\partial w} = \frac{A_2 f_2 E(U') - (\bar{L}-HL)E(U'r)E[U''(f_2 r-p)](f_1 f_{22} - f_{12})}{Df_1} \qquad (24)$$

$$\frac{\partial F}{\partial w} = \frac{A_1 f_2 E(U') - E(U'r)[(\bar{L}-HL)E\{U''(f_1 r-w)\} - E(U')](f_2 f_{11} - f_1 f_{12})}{Df_1} \qquad (25)$$

Assuming complementarity of the inputs, the signs of $\frac{\partial L}{\partial w}$ and $\frac{\partial F}{\partial w}$ depend on farmer's risk-behavior. We consider two cases separately: 1) the farmer as a net demander of labor, and 2) the farmer as a net supplier of labor. In general, the smaller the farmer, the chances are higher that he is a net supplier of labor.

In the former case, in the absence of uncertainty, $\frac{\partial L}{\partial w} < 0$ and $\frac{\partial F}{\partial w} < 0$. The same results hold good in the case of output uncertainty also, provided the farmer has non-increasing absolute risk-aversion. In the latter case, in the absence of uncertainty, both $\frac{\partial L}{\partial w}$ and $\frac{\partial F}{\partial w}$ are indeterminate. The same is true with output uncertainty, provided the farmer has non-increasing absolute risk-aversion. But if a net supplier of labor (that is, a poor farmer) has increasing absolute risk-aversion, then it can be shown that $\frac{\partial L}{\partial w} < 0$ and $\frac{\partial F}{\partial w} > 0$. It clearly follows that if the farmer is a net demander of labor, $\frac{\partial E(Q)}{\partial w}$ is negative, implying that a marginal increase in wage rate will adversely affect his expected output. But in the case of a net supplier of labor, under either assumption regarding his risk-averse behavior the effect of a marginal change in wage rate on expected output is indeterminate.

In a similar manner, we can get expressions for $\frac{\partial L}{\partial p}$ and $\frac{\partial F}{\partial p}$. The results are exactly similar to that of case (1) above.

An important policy conclusion is that the effects of factor price changes are similar in character in an uncertain environment compared to deterministic models. Thus, for example, in the case of farmers who are net demanders of labor, implementation of agricultural minimum wage will probably lead to a reduction in the use of inputs complementary to labor and as such to a reduction in expected output. Also, a reduction in the price of fertilizer by government subsidization will lead to increased labor utilisation and hence increased expected output.

But, in the case of a farmer who is a net supplier of labor, the effects of such policies are indeterminate in both certain and uncertain environments.

II.3.3. Production Effects of Policies Affecting Farm Size

A great debate has been going on among agricultural economists during the last few decades regarding the cause of the observed inverse relationship between farm size and productivity per hectare.[17] The issue received much attention because discovering its cause has important policy significance in the context of land reform measures. The most popular arguments within the framework of deterministic models are based on variable cost of labor and land quality.

A related controversy involves the efficiency of different types of tenurial arrangements in peasant economies, especially between fixed and share rents. It is a common observation that both of these arrangements simultaneously exist in several areas. In a thorough study of share tenancy in the context of Taiwan, Cheung[18] argued that share contracts are efficient and are more widespread in high-risk areas compared to fixed rent contracts. But Rao[19] argued, based on Indian data, that fixed-rent contracts are more widespread in situations involving high-risk as compared to share-contracts which are more prevalent in situations involving less scope for decision making in the face of uncertainty. According to Rao, more risky farming is characterised by fixed rent contracts implying that the entire burden of risk is borne by the farmer himself. Another observation by Rao, based on Indian data is that on the average sharecropping is resorted by small farmers essentially for augmenting factor incomes through the fuller use of own resources such as family labor and bullocks, whereas big farmers lease in land at fixed cash rents with a view to earning profits. Also, Stiglitz[20] pointed out that assuming equal transaction costs of wage, lease and share contracts, the risk-sharing function of share contracts is redundant since combinations of wage and lease contracts can achieve the same thing. Thus it is apparent that the controversy remains unresolved.

With the above discussion as background, we shall analyse the implications of a marginal change in farm size in the context of our model. Implicit differentiation of (4) and (5) with respect to H and simultaneous solution of the corresponding equations, after some simplifications, yield

$$\frac{\partial L}{\partial H} = \frac{M\ E(U'r)(f_1 f_{22} - f_2 f_{12})}{D f_2} \qquad (26)$$

$$\frac{\partial F}{\partial H} = \frac{M\ E(U'r)(f_2 f_{11} - f_1 f_{12})}{D f_2} \qquad (27)$$

where

$$M = -\ E[U''(fr - wL - pF)(f_2 r - p)]$$

Assuming $f_{12} > 0$, the signs of $\frac{\partial L}{\partial H}$ and $\frac{\partial F}{\partial H}$ will be opposite to that of M. Using the definition of Y, we can write M as

$$M = - E[U''(\frac{Y}{H} - \frac{w\bar{L}}{H})(f_2 r-p)]$$

$$= \frac{1}{H} E[R_R U'(f_2 r-p)] - \frac{w\bar{L}}{H} E[R_A U'(f_2 r-p)]$$

where $R_A = -\frac{U''}{U'}$ is the absolute risk-aversion function and $R_R = -\frac{U''}{U'} Y$ is the relative risk-aversion function respectively. Using the first order conditions and the definition of covariance of two random variables, M can be further simplified and written as

$$M = \frac{1}{H} \text{Cov } [R_R, U'(f_2 r-p)] - \frac{w\bar{L}}{H} \text{Cov } [R_A, U'(f_2 r-p)]$$

Now, $U'(f_2 r-p)$ is positively monotone with respect to $E[U'(f_2 r-p)]=0$. If R_R is non-decreasing,[21] then by using the definition of generalized correlation[22] we can see that the first covariance is positive. Similarly, if R_A is non-increasing the second covariance is negative. Thus, if the farmer's behavior is characterised by non-decreasing relative risk-aversion and non-increasing absolute risk-aversion,[23] then the first covariance is positive and the second covariance is negative so that M is positive. It easily follows that $\frac{\partial L}{\partial H} < 0$ and $\frac{\partial F}{\partial H} < 0$. A similar result was derived by Srinivasan[24] using a one input model and employing the same set of assumptions regarding farmer's risk-behavior.

If we define output per hectare as Q' = fr so that

$E(Q') = f$, then it easily follows that $\frac{\partial E(Q')}{\partial H} = (f_1 \frac{\partial L}{\partial H} + f_2 \frac{\partial F}{\partial H})$ is negative. But $\frac{\partial E(Q)}{\partial H} = H^*(f_1 \frac{\partial L}{\partial H} + f_2 \frac{\partial F}{\partial H}) + f$ remains indeterminate in sign.

We shall evaluate our conclusions in the context of the discussion at the beginning of this section regarding the farm size productivity controversy and tenurial arrangements. First, it is clear that even without any imperfections in the factor and product markets, the inverse relationship between farm size and productivity can be sustained if we assume that farmer's behavior under production uncertainty conform to reasonable assumptions regarding risk-aversion. Relating these conclusions to the tennurial arrangement controversy, it is clear that if one supports Rao's and Stiglitz' arguments then share tenancy will not weaken the above results. Rather, one can conclude that breaking down of large agrarian holdings into small peasant farms and distributing them to actual cultivators and eliminating share tenancy will increase the expected agricultural output. If one adopts Cheung's argument, still breaking down of large holdings is beneficial from the point of expected output, but the results of elimination of share tenancy are not clear.

Apart from efficiency aspects, land reforms involve important distributional considerations also. Even in a country like India, where the man-land ratio is very high, the concentration of land holding is very high. For example, less than five percent of the rural households in

India control more than 35 percent of the cultivated area. A good proportion of tenancy arrangements are on the basis of oral lease. In the wake of green revolution the landlords have become more commercial minded and the old system of patron-client relations are fast disappearing. Indeed, lax and ineffective land reform measures have added an extra dimension to the existing uncertainty. The accompanying social tensions and economic problems are strongly stated in Frankel [1971, chapter 7] and S. Sen [1975, chapter 12], for example.

II.3.4. Effects of Policies Affecting Labor Supply

Here we trace the impact of a marginal change in total labor supply of the farmer. This could be due to one or more of several factors which may be direct or indirect effects of public policies. Thus the long-run effect of a vigorous family planning program may be reduced supply of labor on the part of a typical peasant family, whereas in the short-run this may actually increase the labor supply by relieving the peasant women from perpetual child-bearing. Improved health services, especially public health programs directed at eradication of debilitating communicable diseases may reduce mortality and morbidity among peasants. This may substantially increase the supply of labor especially if measured in efficiency units. Improved nutrition will have a similar effect. Breakup of joint families may reduce the total labor supply of the household; but it may give an incentive for everybody to work harder. Also education and adult literacy programs may have considerable impact on farm labor supply. It is possible that education, by enlarging his mental horizon may increase the farmer's preference for leisure. But at the same time this very fact may increase his material wants and to acquire them he may be ready to work harder and longer. In any case education will improve the quality of labor, and, indeed, in terms of efficiency units, his labor supply may increase.

Differentiating (4) and (5) with respect to $\bar{L}$ and proceeding as before,

$$\frac{\partial L}{\partial \bar{L}} = \frac{(f_2 f_{12} - f_1 f_{22})}{D} \frac{w}{f_1} E(U'r)E[U''(f_1 r - w)] \tag{28}$$

$$\frac{\partial F}{\partial \bar{L}} = \frac{(f_1 f_{12} - f_2 f_{11})}{D} \frac{w}{f_2} E(U'r)E[U''(f_2 r - p)] \tag{29}$$

If the inputs are complementary and the farmer has non-increasing absolute risk-aversion, it can be shown that $\frac{\partial L}{\partial \bar{L}}$ and $\frac{\partial F}{\partial \bar{L}}$ are both positive. It is an easy matter to see that $\frac{\partial E(Q)}{\partial \bar{L}}$ is also positive. That is, under reasonable assumptions regarding risk-behavior and the form of the production function, our model predicts that an increase (decrease) in farmer's labor supply will lead to increased (decreased) use of every variable input and hence to increased (decreased) expected output. The intuition of this result is that effectively an increase in $\bar{L}$ scales up expected output and allows maximum losses to be reduced by an increase in L and F. But we are unable to obtain the magnitude of $\frac{\bar{L}}{L} \frac{\partial L}{\partial \bar{L}}$ and as such it is not clear whether the farmer's sale or purchase of labor will increase or decrease depending on whether he is a net supplier or demander of labor.

Though the above results may appear to be straightforward, it should be noted that our conclusions crucially depend on the assumption regarding the shape of absolute risk-aversion function. If farmers have increasing absolute risk-aversion then the results will be reversed. Also, if the farmer is risk-neutral both $\frac{\partial L}{\partial \bar{L}}$ and $\frac{\partial F}{\partial \bar{L}}$ reduce to zero implying that a change in labor supply will have no effect on factor use and hence expected output. The entire change in labor will be adjusted in the market.

II.3.5. Income Tax and the Farmer

Income tax plays only a minor role in most developing countries, either as a source of government revenue or as a tool of income distribution. Another feature is its selective nature. In many of these countries there is some sort of urban income taxation, but usually there is no similar tax on rural incomes. On horizontal equity grounds this differential treatment can be objected to. But extension of income tax to agriculture is usually resisted on grounds that this may adversely affect agricultural production. But these objections need not necessarily be true if uncertainty in agricultural output is explicitly taken into account. Here we consider the effects of marginal changes or introduction of agricultural income tax on farmer's behavior.

First we consider a proportional income tax. The after-tax income is given by

$$Y = [Hfr + w(\bar{L} - HL) - pHF](1-t)$$

where t is the tax rate. Implicit differentiation of the first order conditions with respect to t and evaluation of the derivatives at t = 0, yield

$$A_1 \frac{\partial L}{\partial t} + B_1 \frac{\partial F}{\partial t} = E[U''Y(f_1 r-w)] \quad (30)$$

$$B_1 \frac{\partial L}{\partial t} + A_2 \frac{\partial F}{\partial t} = E[U''Y(f_2 r-p)] \quad (31)$$

If farmer has non-decreasing relative risk-aversion it is easy to see that R.H.S. of both (30) and (31) are non-positive. Further assuming $f_{12} \geq 0$, solution of (30) and (31) will show that both $\frac{\partial L}{\partial t}$ and $\frac{\partial F}{\partial t}$ are non-negative. It is clear that $\frac{\partial E(Q)}{\partial t} \geq 0$. That is, introduction of a proportional income tax or a marginal increase in the existing tax rate will induce the farmer to employ more of every variable input so that his expected output is increased. But, if the farmer's behavior is characterised by decreasing relative risk-aversion then the results will be just the opposite. If he is risk-neutral, a marginal change in income tax will have no effect on his behavior and hence expected output.

Next we consider a simple form of progressive income tax, namely a linear tax with an exemption level and a marginal rate which applies both above and below the exemption level.[26] The after-tax income can be written as

$$Y = [Hfr + w(\bar{L} - HL) - pHF - K](1-t) + K$$

where K is the exemption level and t is the marginal tax rate. Proceeding as before, we get

$$A_1 \frac{\partial L}{\partial t} + B_1 \frac{\partial F}{\partial t} = E[U''(\frac{Y-K}{1-t})(f_1 r-w)] \qquad (32)$$

$$B_1 \frac{\partial L}{\partial t} + A_2 \frac{\partial F}{\partial t} = E[U''(\frac{Y-K}{1-t})(f_2 r-p)] \qquad (33)$$

Further, if the farmer has non-decreasing relative risk-aversion and non-increasing absolute risk-aversion the expressions on the R.H.S. of (32) and (33) can be shown to be negative. With these results, $\frac{\partial L}{\partial t}$ and $\frac{\partial F}{\partial t}$ can both be shown to be positive. Also $\frac{\partial E(Q)}{\partial t}$ is positive. It can be further shown that under other sets of consistent assumptions regarding absolute and relative risk-aversions the signs of $\frac{\partial L}{\partial t}$ and $\frac{\partial F}{\partial t}$ will be indeterminate. Thus we can conclude that under reasonable assumptions regarding risk-behavior, a marginal increase in the progressive tax rate will induce the farmer to employ more of all variable inputs so that his expected output is increased.

In a similar manner we can show that $\frac{\partial L}{\partial K}$, $\frac{\partial F}{\partial K}$ and $\frac{\partial E(Q)}{\partial K}$ are positive if the absolute risk-aversion of the farmer is non-increasing. If he has increasing absolute risk-aversion all these derivatives will have negative signs. Further, if the farmer is risk-neutral, a marginal change in exemption level will have no effect on his behavior and hence his expected output.

Thus we can conclude that with production uncertainty, the impacts of marginal changes in proportional tax rate, progressive tax rate and the level of exemption will all depend crucially on the risk-behavior of the farmer.

Indeed, the above results are extensions of similar results in the analysis of taxation and risk-taking, namely, increased taxation encourages risk-taking under very reasonable assumptions on risk-aversion. Since wage income is certain and income from farming is the risky prospect, the analogy would seem to be appropriate.

It may be further mentioned that the actual implementation of a proportional or progressive income tax on peasants may be extremely difficult. For details of the practical problems involved, see Bird[27] for example. Also we are not thinking in terms of extracting rural surplus for industrialization. Viability considerations may suggest a modified form of 'Graduated Income Tax' similar to those existing in several East African Countries[28] or one similar to the 'Agricultural Holdings Tax' recommended by Raj Committee[29] for India. Also the tax revenue can be used for capital formation and other risk-reducing measures in agriculture.

II.4. Production Under Input and Output Uncertainty

In section II.2, it was assumed that inputs are committed before farming and hence are not subject to uncertainty with respect to weather. But it may be more realistic to assume that the farmer adjusts his decisions regarding the application of inputs as the weather uncertainty unfolds itself through planting, seeding and harvesting seasons. Moreover there may be other random factors affecting the flow of services of different inputs. For example, illness in the family and shortage of hired labor affect the flow of labor input and lack of credit and shortage of fertilizer in the market affect the flow of fertilizer input. Taking these facts into account, here we analyse our original model with uncertainty in inputs as well as output.[30]

As in section II.2, here also we consider a farmer who owns H hectares of land and uses two variable inputs, labor (L) and fertilizer (F) to produce a homogeneous output (Q). But it is assumed that the actual flow of services of labor and fertilizer depend on two random variables u and v respectively. This is to say that we assume that the farmer uses uL and vF amounts of labor and fertilizer instead of the traditional assumption that L and F amounts are used. Further, it is assumed that the output from farming depends on the weather conditions and hence itself is random. The farmer's output is given by

$$Q = Hf(uL, vF)r \tag{34}$$

where uL and vF are random inputs and r is the random index of weather. We assume that the random variables u and v take only non-negative values such that

$$\begin{aligned} E(u) &= E(v) = 1 \\ V(u) &= \sigma u^2,\ V(v) = \sigma v^2 \end{aligned} \tag{35}$$

Other definitions and assumptions remain the same as in section two of this chapter. The farmer's net income (measured in units of output) is given by

$$Y = Hf(uL, vF)r + w(\overline{L} - HL) - pHF \tag{36}$$

where $\overline{L}$ is the total expected labor the farmer himself supplies. It is obvious from (36) that the farmer will sell his surplus labor at the wage rate w, if $\overline{L} > HL$ or buy his excess labor requirements at the same wage, if $\overline{L} < HL$, where HL is the expected labor demand.

As in section II.2, the farmer is assumed to maximise his expected utility of income, E[U(Y)], by the choice of L and F. The corresponding first order conditions are given by

$$HE[U'(Y)\{f_1ur-w\}] = 0 \tag{37}$$

$$HE[U'(Y)\{f_2vr-p\}] = 0 \tag{38}$$

where f_1 and f_2 are partial derivatives of $f(uL,vF)$ with respect to L and F respectively. Hereafter, for convenience we write U, U' and U" for U(Y), U'(Y) and U"(Y) respectively. The second order conditions require that for a maximum:

$$A_1 = \frac{\partial^2 E[U]}{\partial L^2} = E[H\ U''\{f_1ur-w\}^2+U'f_{11}u^2r] < 0 \tag{39}$$

and

$$D = \begin{vmatrix} A_1 & B_1 \\ B_1 & A_2 \end{vmatrix} > 0 \tag{40}$$

where

$$A_2 = \frac{\partial^2 E[U]}{\partial F^2} = E[H\ U''\{f_2vr-p\}^2+U'f_{22}v^2r] \tag{41}$$

and

$$B_1 = \frac{\partial^2 E[U]}{\partial L \partial F} = E[H\ U''\{f_1ur-w\}\{f_2vr-p\}+U'f_{12}uvr] \tag{42}$$

Also, (40) implies that $A_2 < 0$. In the subsequent analysis, it is assumed that the second order conditions are satisfied.

II.4.1. Optimal Input Use

We can write (37) as

$$E[U'f_1ur] = w\,E[U']$$

or

$$E[U']\,E(f_1ur] + Cov[U',f_1ur] = w\,E[U']$$

or

$$E[f_1ur] = w - \frac{Cov[U',f_1ur]}{E[U']} \tag{43}$$

Similarly, from (38) we get

$$E[f_2vr] = p - \frac{Cov[U',f_2vr]}{E[U']} \tag{44}$$

If the farmer is risk-neutral, that is if U' = constant, then

$$Cov[U',f_1ur] = Cov[U',f_2vr] = 0$$

Therefore, from (43) and (44) it follows that a risk-neutral farmer applies inputs up to the level at which the expected values of the marginal products are equated to the respective market prices. In other words, for a risk-neutral farmer, the risk premium is zero.[31] When the farmer's behavior is not characterised by risk-neutrality, that is when $U'' \neq 0$, the covariances are in general indeterminate in sign. However, if the elasticities of the marginal product curves for both inputs have absolute values less than unity, that is, if

$$\eta = \frac{uLf_{11}}{f_1} > -1 \tag{45}$$

$$\varepsilon = \frac{vFf_{22}}{f_2} > -1 \tag{46}$$

then it can be shown that[32]

$$\text{Sign Cov}[U', f_1 ur] = \text{Sign Cov}[U', f_2 ur] = \text{Sign } U''$$

It follows from (43) and (44) that for a risk-averse farmer, that is, for $U'' < 0$,

$$E[f_1 ur] > w$$

$$E[f_2 vr] > p$$

Because of the concavity of f, these results imply that a risk-averse farmer applies less of both inputs than a risk-neutral farmer. Since most production functions commonly used for empirical estimation in agriculture satisfy the above-mentioned constraints on the elasticity of marginal product curves,[33] the above results are reasonable.

If the farmer were to cultivate under conditions of certainty, then the first order conditions for utility maximum are:

$$f_1(L,F) = w \tag{47}$$

$$f_2(L,F) = p \tag{48}$$

as compared to

$$E[f_1 ur] = w \tag{49}$$

$$E[f_2 vr] = p \tag{50}$$

for the risk-neutral farmer.

Now, if the elasticities of marginal product curves as defined in (45) and (46) are non-increasing functions of input services, that is, if $\frac{\partial\eta}{\partial uL} \leq 0$ and $\frac{\partial\varepsilon}{\partial vF} \leq 0$ and the inputs complement one another less and less as more of each input is employed, that is, if $f_{1\,22} < 0$ and $f_{2\,11} < 0$, then it can be shown that[34]

$$E[f_1 ur] < f_1 \quad (51)$$

$$E[f_2 vr] < f_2 \quad (52)$$

if r is independent of u and v.[35]

Equations (51) and (52) along with (49) and (50) imply that a risk-neutral farmer applies less of each input than a farmer cultivating under conditions of certainty. From this and what we have seen earlier it follows that a risk-averse farmer applies less of each input under uncertainty compared to certainty. The implications of these results on expected output are straightforward. It may be illuminating to note that in section 2 of this chapter, we have seen that under output uncertainty a risk-neutral farmer behaves just like a farmer operating under conditions of certainty as far as his input decisions are concerned. But with both input and output uncertainty even a risk-neutral farmer may employ less of each input as compared to complete certainty or just output uncertainty.

II.4.2. Production Effects of Factor Price Policies

First we shall consider a change in wage rate, the price of fertilizer remaining constant. Differentiation of (37) and (38) with respect to w yields, after rearrangement of terms

$$A_1 \frac{\partial L}{\partial w} + B_1 \frac{\partial F}{\partial w} = E[U'] - (\bar{L}-HL)E[U''(f_1ur-w)] \qquad (53)$$

$$B_1 \frac{\partial L}{\partial w} + A_2 \frac{\partial F}{\partial w} = -(\bar{L}-HL)E[U''(f_2vr-p)] \qquad (54)$$

where A_1, A_2 and B_1 are as defined by (39), (41) and (42). Right hand sides of (53) and (54) are in general indeterminate. However, if absolute risk-aversion $R_A = \frac{-U''}{U'} = c$, is a constant, then right hand side of (53) reduces to $E[U']$ and that of (54) to zero. Substituting these values and solving (53) and (54) simultaneously,

$$\frac{\partial L}{\partial w} = \frac{A_2 E[U']}{D} < 0$$

and

$$\frac{\partial F}{\partial w} = \frac{-B_1 E[U']}{D} \lesseqgtr 0$$

according as $B_1 \gtreqless 0$.

But from (42), B_1 is given by

$$B_1 = E[H\ U''\{f_1ur-w\}\{f_2vr-p\}+U' f_{12}uvr]$$

$$= -HC\ E[U'\{f_1ur-w\}\{f_2vr-p\}]+E[U' f_{12}uvr]$$

If the inputs are complementary in the stochastic sense, then the second expectation term is obviously positive. But the first expectation term is indeterminate. It will reduce to zero if the farmer is risk-neutral. Hence we can conclude that in general B_1 is indeterminate in sign.

Summing up, if the farmer's behavior is characterised by constant absolute risk-aversion, then the demand curve for labor is downward sloping; but a change in wage rate has an indeterminate effect on the demand for fertilizer, in general. Only if the farmer is risk-neutral, the effect becomes determinate, in which case a change in wage rate will affect the demand for fertilizer in the same direction.

Similarly, we can show that, under the assumption of constant absolute risk-aversion, the demand for fertilizer is downward sloping, but a change in fertilizer price has in general an indeterminate effect on the demand for labor.

Since there is an intrinsic interest in the effects of factor price changes on the output of agriculture, especially in the context of peasant economies, we may consider the following. As output is random, we have to analyse the effects of changes on the expected output. We have

$$E(Q) = H\ E(fr)$$

Therefore

$$\frac{\partial E(Q)}{\partial w} = H[E(f_1 ur)\ \frac{\partial L}{\partial w} + E(f_2 vr)\ \frac{\partial F}{\partial w}]$$

We have seen that if the farmer has constant absolute risk-aversion and if $B_1 > 0$, then both $\frac{\partial L}{\partial w}$ and $\frac{\partial F}{\partial w}$ are negative, in which case $\frac{\partial E(Q)}{\partial w}$ is negative. That is, a rise in wage rate will lead to a reduction in expected output. But if $B_1 < 0$, then $\frac{\partial L}{\partial w}$ and $\frac{\partial F}{\partial w}$ are of opposite signs and hence $\frac{\partial E(Q)}{\partial w}$ will be indeterminate. Similar results can be obtained for a change in fertilizer price also.

An important conclusion, within the limitations of our model, is that the effect of price changes of inputs may not be as predictable in an uncertain environment as compared to deterministic models. Also the results are more indeterminate in the case of simultaneous uncertainty in inputs and output as compared to only output uncertainty. In the present case we get definitive results only for the special case of constant absolute risk-aversion and $B_1 > 0$.

II:4.3. Production Effects of Policies Affecting Farm Size

Total differentiation of (37) and (38) with respect to H and rearrangement of the resulting terms yield

$$A_1 \frac{\partial L}{\partial H} + B_1 \frac{\partial F}{\partial H} = M_1 \qquad (55)$$

$$B_1 \frac{\partial L}{\partial H} + A_2 \frac{\partial F}{\partial H} = M_2 \qquad (56)$$

where

$$M_1 = -E[U''\{fr-wL-pF\}(f_1ur-w)]$$

$$M_2 = -E[U''\{fr-wL-pF\}(f_2vr-p)]$$

Using the definition of Y, M_1 can be written as

$$M_1 = -E[U''\{\frac{Y}{H} - \frac{W\bar{L}}{H}\}(f_1ur-w)]$$

$$= -\frac{1}{H}E[U''Y(f_1ur-w)] + \frac{W\bar{L}}{H}E[U''(f_1ur-w)]$$

$$= \frac{1}{H}E[R_R U'(f_1ur-w)] - \frac{W\bar{L}}{H}E[R_A U'(f_1ur-w)]$$

In general the two expectation terms are indeterminate. If R_R and R_A are constant, M_1 vanishes by (37). But the only consistent case in which both risk-aversion functions are constant is the case of risk-neutrality. Similarly we can see that M_2 also reduces to zero if the farmer is risk-neutral. In this special case the simultaneous solution of (55) and (56) yields $\frac{\partial L}{\partial H} = \frac{\partial F}{\partial H} = 0$.

Thus, under the naive assumption of risk-neutrality on the part of the farmer we find that the input use per hectare of land remains unchanged when the farm size changes. It is unfortunate that we cannot infer the directions of change under the more interesting assumptions regarding risk-behavior as we were able to do in the case of output uncertainty. Here, since the factor use per hectare remains unchanged under farm size change, it is clear that the expected output per hectare remains unchanged. But it is a simple matter to see that a change in farm size will change the total output in the same direction. Perhaps we can make a general statement that the response of large farmers to redistributive land reform will not be so as to reduce factor use per hectare and as such may not reduce the expected output per hectare. Actually this conclusion was arrived at by Roumasset[36] in his empirical study of fertilizer use of Filippino rice farmers. Though Roumasset considered only output uncertainty, his samples consisted of large farmers for whom risk-neutrality may be a reasonable behavioral assumption.

II.4.4. Production Effects of Policies Affecting Labor Supply

Here we are interested in tracing the impact of a marginal change in the total expected labor supply of the farmer. This change could be due to one or more of the several reasons we have already discussed in section 3.4 of this chapter. The only difference is that as against actual labor supply earlier, here we are concerned about expected labor supply. Total differentiation of (37) and (38) with respect to $\bar{L}$, after rearrangement of terms, yields

$$A_1 \frac{\partial L}{\partial \bar{L}} + B_1 \frac{\partial F}{\partial \bar{L}} = -w\, E[U''(f_1 ur-w)] \quad (57)$$

$$B_1 \frac{\partial L}{\partial \bar{L}} + A_2 \frac{\partial F}{\partial \bar{L}} = -w\, E[U''(f_2 vr-p)] \quad (58)$$

Consider $E[U''(f_1 ur-w)] = -E[R_A\, U'(f_1 ur-w)]$. It is obvious that if R_A is a constant, then by (37) this expectation term vanishes which implies that the right hand side of (57) reduces to zero. Similarly the right hand side of (58) also reduces to zero. It immediately follows that

$\frac{\partial L}{\partial \bar{L}} = \frac{\partial F}{\partial \bar{L}} = 0$ which also implies that the expected output will remain unchanged. Hence we have the conclusion that any change in the farmer's own expected labour supply will have no effect on the intensity of cultivation if his risk-behavior is characterised by constant absolute risk-aversion. That is, any change in the expected family labor will be adjusted in the labor market. It may be interesting to contrast this result with the one we obtained in section II.3.4 where only output uncertainty was considered. There it was found that if the farmer's behavior is characterised by decreasing absolute risk-aversion, then the intensity of cultivation changes in the same direction as that of the actual family labor supply.

II.4.5. Income Tax and the Farmer

First we shall consider a proportional income tax. The after-tax income is given by

$$Y = [H\ f(uL,vF)r + w(\bar{L}-HL) - pHF](1-t)$$

where t is the tax rate. Totally differentiating the corresponding first order conditions with respect to t, evaluating the derivatives at t = 0 and rearranging the terms, we get

$$A_1 \frac{\partial L}{\partial t} + B_1 \frac{\partial F}{\partial t} = E[U''Y(f_1ur-w)] \qquad (59)$$

$$B_1 \frac{\partial L}{\partial t} + A_2 \frac{\partial F}{\partial t} = E[U''Y(f_2vr-p)] \qquad (60)$$

Using the definition of relative risk-aversion,

$$E[U''Y(f_1ur-w)] = -E[R_R U'(f_1ur-w)]$$

In general this expression is indeterminate. However, if we assume $R_R = c$, a constant, then

$$E[U''Y(f_1ur-w)] = -c\ E[U'(f_1ur-w)] = 0$$

by (37). Under the same assumption $E[U''Y(f_2vr-p)] = 0$. With these results, simultaneous solution of (59) and (60) yields $\frac{\partial L}{\partial t} = \frac{\partial F}{\partial t} = 0$. Thus we see that if the farmer's behavior is characterised by constant relative risk-aversion, then a marginal change in proportional income tax will have no effect on his input use. It easily follows that $\frac{\partial E(Q)}{\partial t} = 0$. These results may be contrasted with the corresponding results in section 3.5 of this chapter where we found that under the assumption of non-decreasing relative risk-aversion $\frac{\partial L}{\partial t}$ and $\frac{\partial F}{\partial t}$ are both non-negative provided the inputs complement each other. Hence we may conclude that the effect of marginal change in proportional income tax is qualitatively the same in both cases.

Next we consider a simple form of progressive income tax, namely a linear tax with an exemption level and a marginal rate which applied both above and below the exemption level. The after-tax income can be written as

$$Y = [Hf(uL,vF)r+w(\bar{L}-HL)-pHF-K](1-f)+K$$

where K is the exemption level and t is the marginal tax rate. Proceeding as before and using the definition of Y, we get

$$A_1 \frac{\partial L}{\partial t} + B_1 \frac{\partial F}{\partial t} = E[U''\{\frac{Y-K}{1-t}\}(f_1ur-w)] \quad (61)$$

$$B_1 \frac{\partial L}{\partial t} + A_2 \frac{\partial F}{\partial t} = E[U''\{\frac{Y-K}{1-t}\}(f_2vr-p)] \quad (62)$$

Using the definitions of R_A and R_R,

$$E[U''\{\frac{Y-K}{1-t}\}(f_1ur-w)] = -\frac{1}{1-t} E[R_R U'(f_1ur-w)]$$

$$+\frac{K}{1-t} E[R_A U'(f_1ur-w)]$$

In general these expectation terms are indeterminate in sign. However, if the farmer has constant absolute and relative risk-aversions, then both expressions reduce to zero. But these assumptions are consistent only in the risk-neutral case. Similarly the expression on the right hand side of (62) also vanishes under risk-neutrality. Solving (61) and (62) we can easily see that $\frac{\partial L}{\partial t} = \frac{\partial F}{\partial t} = 0$. Also $\frac{\partial E(Q)}{\partial t} = 0$. This result is to be compared to the one obtained in section 3.5 under output uncertaintly where we found that under increasing relative risk-aversion and non-increasing absolute risk-aversion both $\frac{\partial L}{\partial t}$ and $\frac{\partial F}{\partial t}$ are positive. We may argue that risk-neutrality is a reasonable behavior-assumption for wealthy farmers and as such an increase in the marginal tax rate may not reduce the intensity of their cultivation and hence their expected output.

In a similar manner we can show that $\frac{\partial L}{\partial K}$, $\frac{\partial F}{\partial K}$ and $\frac{\partial E(Q)}{\partial K}$ are all indeterminate in general. But all of them reduce to zero if the farmer's behavior is characterised by constant absolute risk-aversion.

Thus we may conclude that under simultaneous uncertainty in inputs and output the impacts of marginal changes in the tax parameters are in general indeterminate. However, under certain restrictive, albeit, reasonable assumptions regarding farmer's risk-behavior, we find that these marginal changes have no effect on the intensity of cultivation and hence the expected output.

II.4.6. Farmer Response to Marginal Impacts on Output Uncertainty

So far we were concerned with the overall impact of uncertainty. Here we are interested in the marginal impacts of uncertainty on the farmer behavior, that is, the effects of marginal changes in the moments of the distribution of the random variable r. First we consider a 'risk-preserving' shift in the distribution. Following the procedure adopted in section 3.1 of this chapter, we define $r^* = r+\theta$, where θ is a shift parameter with zero as the initial value. Replacing r by r* in (36), the first order conditions become

$$E[U'\{f_1 u(r+\theta)-w\}] = 0$$

$$E[U'\{f_2 v(r+\theta)-p\}] = 0$$

Totally differentiating these equations with respect to θ and evaluating the derivatives at $\theta = 0$, we obtain after some simplifications

$$A_1 \frac{\partial L}{\partial \theta} + B_1 \frac{\partial F}{\partial \tau} = -H\ E[U''f(f_1ur-w)]-E[U'f_1u] \tag{63}$$

$$B_1 \frac{\partial L}{\partial \theta} + A_2 \frac{\partial F}{\partial \theta} = -H\ E[U''f(f_2vr-p)]-E[U'f_2v] \tag{64}$$

The terms on the right hand sides of (63) and (64) are determinate only in the risk-neutral case and then both are negative. Denoting them as M_1 and M_2, respectively, simultaneous solution of (63) and (64) yields

$$\frac{\partial L}{\partial \theta} = \frac{A_2M_1-B_1M_2}{D}$$

and

$$\frac{\partial F}{\partial \theta} = \frac{A_1M_2-B_1M_1}{D}$$

It follows that both $\frac{\partial L}{\partial \theta}$ and $\frac{\partial F}{\partial \theta}$ are positive if $B_1 \geq 0$. But in the risk-neutral case, from (42), we can see that $B_1 = U'E(f_{12}uvr)$. If the inputs are complements in the stochastic sense, that is if $f_{12} > 0$ for all realizations of u and v, then B_1 is obviously positive. This implies that a rightward shift in the distribution of the random variable representing the effect of weather on the farm output will lead to increased use of both inputs and hence increased expected output, provided the farmer is risk-neutral. If one treats technological progress or use of high yielding varieties of seeds as equivalent to a rightward shift of r without changing its variance, one can conclude that under some general conditions these will lead to increased use of both inputs and hence increased expected output.

Next we shall consider the effects of a change in the riskiness of the distribution of r without changing its mean. Following the procedure adopted in section 3.1 of the present chapter, define $r^* = \delta r+\theta$, where δ and θ are two shift parameters with initial values as one and zero respectively, such that $dE(\delta r+\theta) = 0$ which implies $\frac{d\theta}{d\delta} = -1$. Replacing r by r* in (36), the first order conditions become

$$E[U'\{f_1u(\delta r+\theta)-w\}] = 0$$

and

$$E\{U'\{f_2v(\delta r+\theta)-p\}] = 0$$

Differentiation of these equations with respect to δ and simplifications yield

$$A_1 \frac{\partial L}{\partial \delta} + B_1 \frac{\partial F}{\partial \delta} = M_1 \tag{65}$$

and

$$B_1 \frac{\partial L}{\partial \delta} + A_2 \frac{\partial F}{\partial \delta} = M_2 \tag{66}$$

where

$$M_1 = -H\ E[U''f(r-1)(f_1ur-w)]-E[U'f_1u(r-1)]$$

and

$$M_2 = -H\ E[U''f(r-1)(f_2vr-p)]-E[U'f_2v(r-1)]$$

M_1 and M_2 are determinate only if the farmer is risk-neutral and r is independent of both u and v. In this special case both M_1 and M_2 reduce to zero which implies that $\frac{\partial L}{\partial \delta} = \frac{\partial F}{\partial \delta} = 0$ and hence $\frac{\partial E(Q)}{\partial \delta} = 0$. These results imply that a change in the riskiness of the random variable representing product uncertainty has no effect on the intensity of farming and hence on the expected output. It is obvious that this simplistic result critically depends on the assumption of risk neutrality.

II.4.7. Farmer Response to Marginal Impacts on Input Uncertainty

Here we consider a shift in the distribution of the random variable u associated with labor input, without changing its variance. Replace u by $u^* = u+\theta$, with zero as initial value of θ. Therefore (36) becomes

$$Y = Hf((u+\theta)L,vF)r+w(\bar{L}-HL)-pHF$$

The corresponding first order conditions are

$$E[U'\{f_1(u+\theta)r-w\}] = 0$$

and

$$E[U'\{f_2vr-p\}] = 0$$

Total differentiation of these equations with respect to θ and simplification yield,

$$A_1 \frac{\partial L}{\partial \theta} + B_1 \frac{\partial F}{\partial \theta} = M_1 \qquad (67)$$

and

$$B_1 \frac{\partial L}{\partial \theta} + A_2 \frac{\partial F}{\partial \theta} = M_2 \qquad (68)$$

where

$$M_1 = -HLE[U''f_1r(f_1ur-w)]-E[U'(f_1r+f_{11}urL)]$$

and

$$M_2 = -HLE[U''f_1r(f_2vr-p)]-LE[U'f_{21}vr]$$

In general, M_1 and M_2 are indeterminate. However, if the farmer is risk-neutral, then

$$M_1 = -E[U'(f_1r+f_{11}urL)]$$

and

$$M_2 = -LE[U'f_{21}vr]$$

Now

$$M_1 = -U'E[f_1r(1 + \frac{f_{11}uL}{f_1})]$$

$$= -U'E[f_1r(1 + \eta)]$$

If we invoke a condition used in section II.4.1, namely

$\eta > -1$, then obviously M_1 is negative. If the factors complement each other in production (that is, if $f_{12} > 0$), then M_2 is also negative. Solving (67) and (68) simultaneously,

$$\frac{\partial L}{\partial \theta} = \frac{A_2M_1-B_1M_2}{D}$$

and

$$\frac{\partial F}{\partial \theta} = \frac{A_1M_2-B_1M_1}{D}$$

If $B_1 \geqq 0$, then both $\frac{\partial L}{\partial \theta}$ and $\frac{\partial F}{\partial \theta}$ are positive. But it can be easily seen that under risk-neutrality and complementarity of factors, $B_1 > 0$.

Thus we have the proposition that, if the farmer's behavior is characterised by risk-neutrality and the production function satisfies some plausible assumptions, then a rightward shift in the distribution of the random variable associated with labor input will lead to increased use of both inputs. One may consider improvement in health conditions in rural areas and better labor mobility as examples of such a shift. Similarly, it can be shown that a rightward shift in the distribution of the random variable associated with fertilizer use also will lead to increased use of both inputs. Better credit facilities in rural areas and improved marketing of fertilizer are examples of such shifts.

Next we consider the effects of a change in the riskiness of the distribution of u without changing its mean. Define $u^* = \delta u + \theta$. An increase in δ (from $\delta = 1$ and $\theta = 0$) will blow up all values of u. To restore mean we have to adjust θ simultaneously so that $dE(\delta u + \theta) = 0$. Since $E(u) = 1$, this implies that $\frac{d\theta}{d\delta} = -1$. Farmer's income becomes

$$Y = Hf((\delta u+\theta)L, vF)r + w(\bar{L}-HL) - pHF$$

Differentiating the corresponding first order conditions with respect to δ and using the condition $\frac{d\theta}{d\delta} = -1$ as well as the initial values of δ and θ we get, after rearrangement of terms,

$$A_1 \frac{\partial L}{\partial \delta} + B_2 \frac{\partial F}{\partial \delta} = M_1 \tag{69}$$

and

$$B_1 \frac{\partial L}{\partial \delta} + A_2 \frac{\partial F}{\partial \delta} = M_2 \tag{70}$$

where

$$M_1 = -HLE[U''f_1(u-1)r(f_1ur-w)] - E[U'\{f_{11}(u-1)urL + f_1(u-1)r\}]$$

and

$$M_2 = -HLE[U''f_1(u-1)r(f_2vr-p)] - LE[U'f_{21}(u-1)vr]$$

Obviously, M_1 and M_2 are indeterminate, in general. If we assume that the farmer is risk-neutral, then

$$M_1 = -U'E[f_{11}(u-1)urL+f_1(u-1)r]$$

and

$$M_2 = -LU'E[f_{21}(u-1)vr]$$

Now,

$$M_1 = -U'E[r(u-1)f_1(\frac{f_{11}uL}{f_1} + 1)]$$

$$= -U'E[r(u-1)f_1(1+\eta)]$$

$$= -U'E[(u-1)f_1(1+\eta)]$$

if r is independent of u and v, as E(r) = 1. Since E(u-1) = 0, we get

$$M_1 = -U'Cov[u-1, f_1(1+\eta)]$$

This covariance will be negative if $\frac{\partial\eta}{\partial uL} \leq 0$, that is, if the elasticity of marginal product curve for labor is a non-increasing function of uL. Hence M_1 becomes positive. The validity of the above assumption was discussed in section 4.1 of this chapter. If r is independent of u and v, we can write

$$M_2 = -LU'E[f_{21}(u-1)v]$$

$$= -LU'Cov[u-1, f_{21}v]$$

If we further assume that u and v are independent and $f_{211} < 0$, then the covariance becomes negative so that M_2 is positive. Solving (69) and (70) simultaneously, we get

$$\frac{\partial L}{\partial \delta} = \frac{A_2 M_1 - B_1 M_2}{D}$$

and

$$\frac{\partial F}{\partial \delta} = \frac{A_1 M_2 - B_1 M_1}{D}$$

Further, we can easily show that when the farmer is risk-neutral $B_1 > 0$. That is, $\frac{\partial L}{\partial \delta}$ and $\frac{\partial F}{\partial \delta}$ are both negative and hence $\frac{\partial E(Q)}{\partial \delta} < 0$.

Hence we have the proposition that, if farmer's behavior is characterised by risk-neutrality, if the random variables associated with inputs and output are independent and if the production function satisfies some reasonable assumptions, then a small change in the riskiness of the distribution of the random variable associated with an input will affect the use of both inputs in the opposite direction. Reduced incidence of illness and increased institutional financing of agricultural credit can be considered examples of such risk-reducing factors which will lead to increased use of the variable inputs. It is interesting to note that the corresponding result in section 4.6 of this chapter, where we considered a change in the riskiness of the distribution of the random variable associated with output was that such a risk-change has no effect on the intensity of cultivation if the farmer is risk-neutral.

II.5. Concluding Remarks

A main purpose of this chapter has been to show that a number of important results obtained from deterministic models of peasant economies do not necessarily hold if uncertainty is explicitly taken into account and reasonable assumptions about peasant's risk-behavior are made. An equally important purpose has been to explore the implications of various public policies on the incidence and intensity of uncertainty and on the behavior of the peasants. A basic behavioral assumption has been the risk-averse nature of peasant farmers, especially the small ones. This alone enabled us to establish that it is quite a rational decision on the part of small farmers to employ less of each input than classical marginal analysis would suggest.

Another manifestation of risk-aversion is the reluctance of small farmers to pursue more innovative farming which is inherently more risky. Instead of branding them as 'Conservative' or 'Irrational' a better farm policy may be to implement programs which substantially reduce the riskiness of farming. Further, we found that needed resources can be extracted from the rural sector itself through some sort of practicable income taxation without adversely affecting the expected agricultural output.

The discussion in section 4 clearly indicate that as compared to uncertainty in output alone, simultaneous

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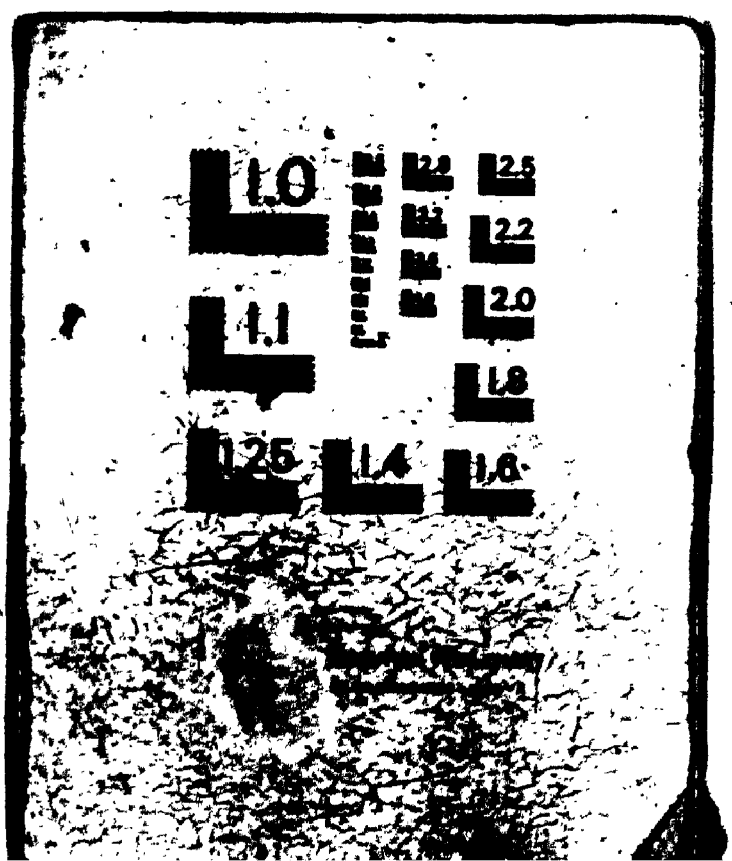

uncertainty in output and inputs makes the model quite complicated. The result is that in a number of cases it is required to impose rather restrictive assumptions regarding farmer's risk-behavior to arrive at definitive conclusions.

That this should be the case ought not to be surprising, since in the present model, apart from r, the random variable associated with the output, we have two random variables u and v enclosed within a non-linear function, f, that forms part of the argument, Y, of another function, U, the expected value of which we maximise. Thus, our problem is inherently much more difficult to solve for definite results than the simpler model considered earlier or for that matter, the standard problems of portfolio choice and the theory of firm.

Our main justification for considering this rather complicated model is that this comes closest to reality in peasant farming where farmers face not only product uncertainty but a host of random factors affecting the actual flow of the services of inputs. Though, in general, randomness in inputs and output may be mutually related, in many cases these random factors may be mutually independent and as such one may be able to identify specific groups of public policies to reduce or overcome each of them.

We have clearly seen that a number of important results obtained from deterministic models of peasant economies do not hold under uncertainty in inputs and output. It was shown that even a risk-neutral farmer may behave differently.

However, our micro results are to be judged in the context of the simplified model behind them. One limitation of the present analysis is its partial equilibrium framework. As such, our policy conclusions cannot be considered as policy prescriptions.

Finally, the present model calls for modifications and extensions in at least four directions. An obvious extension is to develop a general equilibrium two-sector framework with production uncertainty in agriculture and to analyse the implications of public policies. In economies where agricultural price stabilisation policies through Marketing Boards or otherwise are not implemented, price uncertainty may play an equally important role on the behavior of the farmers and as such a similar analysis is called for. In real word situations usually one faces a multitude of random elements and as such any meaningful theory should be able to handle more than one random variable simultaneously. And finally, the very nature of agriculture in present-day developing countries requires a dynamic framework for a more useful discussion of any public policies.

Footnotes

1. Horowitz [1970], Sandmo [1971], Leland [1972], Blair [1974], Batra & Ullah [1974] and Hartman [1976] are some of the important examples. In the development of the present model we make use of some of the techniques developed by these authors.

2. Porter [1959], Dillon and Anderson [1971], Srinivasan [1972], Hazell and Scandizzo [1976] and Wiens [1977] are the major examples of this type.

3. We restrict to two inputs mainly for simplicity. The justification for excluding capital as a variable input is that in most peasant economies capital consists of simple conventional tools, structures, land improvements, simple irrigation devices and farm animals and it may be reasonable to assume that these are proportional to the farm size and as such are taken care of by our definition of the fixed factor 'land'.

4. A more general stochastic formulation of the production function is given by $Q = f(L, F, r)$, similar to those formulated in Leland [1972] and Horowitz [1970]. But this function turns out to be too general to yield categorical results. For this reason and owing to the fact that multiplicatively separable stochastic production functions have been previously used by authors like Sandmo [1971] and Srinivasan [1972], we are using a less general production function.

5. This formulation was originally employed by Srinivasan [1972].

6. For details, see Appendix at the end of the thesis. It is well-known that in order for the utility functions to satisfy the V-M axioms without giving rise to St. Petersburg Paradox, they must be bounded from above. For this reason, we assume that the farmer's utility function has an upper bound.

7. A sufficient condition is continuity of $U(Y)$ in r, L and F and $U'(Y)$ in L and F and $r \varepsilon [r_1, r_2]$.

8. $D > 0 \Rightarrow A_1 A_2 > B_1^2$. Since $A_1 < 0$, A_2 must also be negative for D to be positive.

9. Expanding D and using the first order conditions, we get

$$D = -E[U'' \frac{(f_2 r - p)^2}{f_2}](2f_1 f_2 f_{12} - f_1^2 f_{22} - f_2^2 f_{11})$$

$+[E(U'r)]^2(f_{11}f_{22}-f_{12}^2).$

It is clear that if the farmer is risk-averse, that is if $U'' < 0$, then $(f_{11}f_{22}-f_{12}^2)$ need not be positive to make D positive, provided $(2f_1f_2f_{12}-f_1^2f_{22}-f_2^2f_{11}) > 0$. Also A_1 and A_2 can be negative even when $f_{ii}(i = 1, 2)$ are not negative.

10. When $r < 1$, $Y < E(Y)$ so that $U'(Y) > U'[E(Y)]$. Therefore $U'(Y)f_1(r-1) \leq U'[E(Y)]f_1(r-1)$ for $r < 1$ also.

11. See Hazell and Scandizzo [1976] pp. 2-3.

12. The empirical findings of Roumasset [1976] for Filipino rice farmers is an example.

13. Rothschild and Stiglitz [1970, 1971]. For more details, see Appendix A.4.

14. For theoretical and empirical support, see, for example, Roumasset [1976] pp. 54 and 91 and Rao [1971], pp. 588.

15. This has the interpretation that the willingness to engage in small bets of fixed sizes increases with income, in the sense that the odds demanded diminish. For details, see Appendix A.3.

16. Also we can get this result using another method which has more general application. Write $E[U''(Y)\{f_2r-p\}] = -E[R_A(Y)U'(Y)\{f_2r-p\}] = -Cov[R_A(Y), U'(Y)\{f_2r-p\}]$ using first order condition. Now, $U'(Y)\{f_2r-p\}$ is positively monotone with respect to $E[U'(Y)\{f_2r-p\}] = 0$. If $R_A(Y)$ is decreasing, it is monotone non-increasing also. Then by the definition of Generalised Correlation [see Scheffman (1974), p. 279] we can see that the covariance is negative.

17. A summary of this debate can be found in Bhagwati and Chakravarti [1969].

18. Cheung [1969] Chapter 4, especially.

19. See Rao [1971], pp. 585-587.

20. See Stiglitz [1974], pp. 220.

21. This has the interpretation that if both the size of the bet and income are increased in the same proportion, the willingness to accept the bet does not increase. For details, see Appendix A.3.

22. See Scheffman [1975] pp. 278-79 or follow the argument of footnote 16.

23. By definition $R_R(Y) = R_A(Y)Y$. Differentiation yields $R_R' = R_A'Y + R_A$. We can immediately see that increasing relative risk-aversion and decreasing absolute risk-aversion are consistent as R_A is always nonnegative.

24. Srinivasan [1972] pp. 413-416.

25. These figures are based on National Sample Survey data. For more detailed data regarding the distribution of operational holdings in India, see Sen. S. [1975], appendix table 8.

26. This would imply that the average tax rate measured by $\frac{T}{Y}$ ratio, where T is the tax revenue, is progressive, that is, $\frac{d(T/Y)}{dY} > 0$. See, for example Ahsan [1974].

27. Bird [1974], especially chapters 1-3.

28. Davey [1974] contains a comprehensive study of these taxes.

29. Government of India [1972]: Report of the committee on Taxation of Agricultural Wealth and Income.

30. In the theory of firm, models involving input uncertainty were considered by Walters [1960] and Ratti and Ullah [1976], among others. But none has so far analysed the case of simultaneous uncertainty in inputs and output.

31. For details regarding 'risk premium' see Appendix A.3.

32. We have: $\frac{\partial f_1 ur}{\partial u} = f_1 r + uLf_{11} r = f_1 r[1 + \frac{uLf_{11}}{f_1}] =$

$f_1 r(1+\eta) > 0$ by (45). Also $\frac{\partial f_1 ur}{\partial v} = f_{12} urF > 0$,

$\frac{\partial f_1 ur}{\partial r} = f_1 u > 0$. Further, $\frac{\partial U'}{\partial u} = Hf_1 rLU''$, $\frac{\partial U'}{\partial v} = Hf_2 rFU''$

and $\frac{\partial U'}{\partial r} = HfU''$. Therefore sign Cov(U', $f_1 ur$) = Sig. U".

Similarly Sign Cov(U', $f_2 vr$) = Sign U".

33. Cobb-Douglas, Constant Elasticity of Substitution

and Transcendental Production functions as well as Revankar's Variable Elasticity of Substitution and Constant Marginal Share production functions satisfy these constraints.

34. If r is independent of u and v, then $E[f_1 ur] = E[f_1 u]$ as $E(r) = 1$. Twice applying Jensen's inequality [see Rao, C. R. (1973), p. 58], $E[u\, f_1(uL, vF)] < f_1(L, F)$ if $f_{1\,22} < 0$ and $2\, f_{11} + uLf_{111} < 0$. Now, $2\, f_{11} + uLf_{111} = \frac{\partial}{\partial uL}[f_1(1+\eta)] = f_{11}(1+\eta) + f_1 \frac{\partial}{\partial uL} < 0$ if $\eta > -1$ and η is non-increasing in uL.

35. Though, in general, randomness in inputs and output may be mutually related, in many cases the random factors affecting the flow of inputs may be independent of the weather uncertainty and as such the present assumption may be justified. Thus, for example, labor flow is affected by illness in the family whereas the flow of fertilizer is affected by a shortage in the market.

36. See Roumasset [1976] p. 56.

CHAPTER III

RURAL-URBAN MIGRATION UNDER UNCERTAINTY

III.1. Introduction

For a long time one of the problems which worried development economists most was how to draw sufficient labor force to industry from agriculture without reducing agricultural output. The concept of zero-marginal product of labor in agriculture and different labor surplus models were developed in this context.[1] By early sixties, these classical theories were challenged by neo-classical theories of dualistic economic development.[2] Rejecting zero-marginal productivity and surplus labor, they argued that discrepancy in labor productivity between agriculture and industry was the automatic mechanism that would trigger migration, which would continue until the dualism eventually disappears.

But by late sixties the emphasis shifted from how to get labor for industrialization to how to solve the urban unemployment problem. Despite significant transfers of labor to the urban sector, dualism persisted and perhaps even increased. Also, the unprecedented population growth mainly due to reduction in mortality as a result of improvement in public health programs added an additional dimension to the migration problem.

A perplexing question has been that if migrants move in response to wage differentials, what explains the large and increasing flows of migrants in the face of growing urban unemployment. Todaro [1969] introduced a model in which workers migrate from rural to urban areas in response to differences in the actual earnings in rural areas and expected earnings in urban areas. The main departures of Todaro's model from the previous literature are in introducing an exogeneously fixed minimum wage in the urban areas and in treating urban income as uncertain for the migrant. Based on these simple concepts it is easy to see that urban job creation need not necessarily solve the unemployment problem; it may even worsen the situation.[3] Subsequently a large volume of literature[4] has emerged as modifications and extensions of this model and exploring various public policies for solving the urban unemployment problem.

It is well-known that the rural-urban income disparity is further worsened by the unsteady nature of the income from farming[5] due to natural hazards. In many cases large-scale migration to urban areas follows immediately after extensive crop-failures due to floods, droughts and other natural calamities. Indeed, unpredictable and meager agricultural income translates itself into urban unemployment. Perhaps the most effective solution may be at the root of the problem. But so far no model has been developed introducing uncertainty in agricultural income explicitly into the migration model. In this chapter we develop a simple model of migration with its main stress on the uncertain nature of rural income and discuss the effects of various public policies on migration.

Subsequent to Todaro's work, migration models have given, perhaps, too much emphasis to the role of minimum wage in the urban sector of the economy. In the case of India, for example, according to Fifth Five Year Plan draft report [Government of India, 1973, part I, p. 2-3] there were about 130 million people in the urban areas. At the estimated labor force participation rate of 32%, this implies that the urban labor force was about 42 million. As against this, the total employment in the organised sector of the economy, which includes private, public and government sector, is estimated to be about 18 million. And it may be a safe assumption that any kind of minimum wage is applicable to only the organised sector. Thus, even if one argues that the entire organised labor force is located in urban areas (which is not true, as the organised sector includes plantations and government empolyees located in rural areas, for example), less than half the urban labor force gets the benefit of minimum wages.

Even a casual observer can recognize that a sizable segment of the labor force in the urban areas of developing countries is absorbed in what is usually termed 'urban traditional' or 'murky' sector. Employment in this sector is mostly of self-employment nature which includes a variety of personal services and petty retailing. Most of the unskilled rural migrants are usually absorbed in this sector. Many of them try to enter the organised sector and as such may remain officially unemployed; but they usually earn a positive income, though perhaps much smaller than the minimum wage. This point was stressed by Todaro [1969, p. 139] where he characterized migration as a two-stage phenomenon. Also, existence of a 'murky' sector was taken into account by Fields [1975] in his development of a migration model based on job-search process. The model developed in this paper gives explicit recognition to this aspect of rural-urban migration.

Todaro [1969] and Harris and Todaro [1970] make the implicit assumption that individuals are risk-neutral. Except few[6] most subsequent works in this area follow this restrictive assumption. But as we have argued in the introductory chapter, when faced with uncertainty (whether subjective or objective) the pervasive behavior mode of poor peasants is risk-aversion. We admit that attitudes to risk as measured by risk-aversion will vary both among individuals and, for one individual, among different levels of expected income. In the subsequent analysis we make extensive use of the Arrow-Pratt risk-aversion functions and their properties. Also, as against the usual practice of treating individual as the decision unit, we treat the peasant household as the decision unit.[7]

Given the introduction, the rest of this chapter proceeds as follows. In section two a simple migration model with uncertainty in both rural and urban incomes is introduced and some basic results are derived. But this formulation is mathematically intractable for policy discussions. In order to focus on policy issues, section three concentrates on uncertainty in rural income alone and section four on uncertainty in urban income alone. Results are not developed to the level of policy prescriptions, but rather, the more modest goal is pursued of providing a better understanding of the implications of various public policies on migration. Final section contains a few concluding remarks and a discussion of some possible extensions.

III.2. A General Model and Some Basic Results

We assume that there are two sources of income for a typical peasant household; namely (1) income from farming the land at its disposal and (2) income from jobs in cities. In effect we do not consider the existence of a rural labor market.[8] Income from farming is uncertain due to unpredictable weather conditions. Also, income from work in the city is random due to uncertainty of job prospects. It is further assumed that the household's attitude towards risk can be summarized by a Von Neumann-Morgenstern utility function.[9]

Further, assume that the household has 'n' members in the labor force and it owns 'H' hectares of land. Of the 'n' members 'a' remain on the farm and the remaining 'n-a' go to the city for seeking jobs. The household income from farming (measured in units of homogeneous agricultural output) is given by

$$Y_1 = f(a,H)r_1 \tag{1}$$

where f is the production function, assumed to be concave and r_1 is a continuous random variable reflecting the influence of weather on output such that

$$r_1 \geqq 0, \; E(r_1) = \mu_1 \text{ and } V(r_1) = \sigma_1^2 < \infty .$$

The household income from jobs in the city is given by

$$Y_2 = (n-a)wr_2 \tag{2}$$

where w (also measured in units of agricultural output), the marginal product of labor is the maximum income a migrant can earn in city and r_2 is a continuous random variable such that

$$0 \leqq r_2 \leqq 1, \; E(r_2) = \mu_2 \text{ and } V(r_2) = \sigma_2^2 < \infty .$$

The presence of r_2 implies that the urban earnings of a migrant is a random variable with its range from 0 to w.

The case of minimum wage can be considered as a special case of this formulation where w is the minimum wage and r_2 takes only two values, namely 1 with probability μ_2 and 0 with probability $(1-\mu_2)$. Total household income is given by

$$Y = Y_1 + Y_2 = f(a, H)r_1 + (n-a)wr_2 \quad (3)$$

Household maximizes its expected utility of income by the choice of 'a'. That is, household's problem is

$$\underset{[a]}{\text{Max}}\ E[U\{f(a, H)r_1 + (n-a)wr_2\}]$$

$$= \text{Max} \int_{r_1} \int_{r_2} U\{f(a, H)r_1 + (n-a)wr_2\} dp(r_1, r_2) \quad (4)$$

where $dp(r_1,r_2)$ is the joint density of r_1 and r_2. In order to simplify the analysis we make the assumption that r_1 and r_2 are independently distributed with density functions $dp(r_1)$ and $dp(r_2)$ respectively. This appears to be a reasonable assumption, especially for short-run models like the present one.[10] Assuming certain regularity conditions for differentiation of expected values, the first order condition for an interior extremum is[1]

$$E[U'(Y)\{f_1 r_1 - wr_2\}] = 0 \quad (5)$$

where f_1 represents the partial derivative of the production function with respect to its first argument. Equation (5) can be rewritten as the second term is unambiguously positive. First term is positive, zero or negative depending on whether $R_A' \gtreqless 0$.

Following the procedure of section III.3.5, the effects of proportional and progressive income tax on various types of incomes can be analysed. Below we summarize the effects of proportional income tax on migration.

(1) Tax on entire household income:

$$\frac{\partial a}{\partial t} = - \frac{1}{(1-t)D} \text{Cov}[R_R, U'(Y)\{f_1 - wr_2\}] \lesseqgtr 0 \text{ depending}$$

on whether $R_R' \gtreqless 0$.

(2) Tax on farm income alone:

$$\frac{\partial a}{\partial t} = - \frac{1}{D} \text{Cov}[R_A, U'(Y)\{f_1 - wr_2\}] + \frac{f_1}{D} E[U'(Y)] \lesseqgtr 0$$

if $R_A' \geq 0$ and in determinate if $R_A' < 0$.

(3) Tax on wage income alone:

$$\frac{\partial a}{\partial t} = - \frac{1}{D} \text{Cov}[R_A, U'(Y)\{f_1 - wr_2\}] + \frac{f_1}{D}$$

$$\text{Cov}[R_A, U'(Y)\{f_1 - wr_2\}] - \frac{w}{D} E[U'(Y) r_2] > 0$$

if $U''(Y) = 0$ and depends on the relative magnitudes of the three terms otherwise.

In a similar manner we can analyse the effect of marginal changes in the progressive tax rate and level of exemption on different incomes.

the farm as well as in the city, provided $f(0,H) = 0$, $\lim_{a \to 0} f_1(a,H) > w$ and $f_1(n,H) < w$.

To establish this we need only demonstrate that

$$\frac{d}{da}\,[E\{U(Y)\}]\Big|_{a=0} > 0 \;;\; \frac{d}{da}\,[E\{U(Y)\}]\Big|_{a=n} < 0$$

We will show the first inequality,

$$\begin{aligned}
\frac{d}{da}\,[E\{U(Y)\}]\Big|_{a=0} &= \int_{r_1}\int_{r_2} U'(nwr_2)\{f_1(0,H)r_1 - wr_2\} \\
&\quad dp(r_1)\,dp(r_2) \\
&= \int_{r_1} f_1(0,H)\,r_1\,dp(r_1) \int_{r_2} U'(nwr_2)\,dp(r_2) \\
&\quad -\int_{r_2} wr_2 U'(nwr_2)\,dp(r_2) \\
&= E\{f_1(0,H)r_1\}\,E\{U'(nwr_2)\} \\
&\quad -E\{wr_2 U'(nwr_2)\} \\
&= [E\{wr_2\}+K]\,E\{U'(nwr_2)\} \\
&\quad -E\{wr_2 U'(nwr_2)\}
\end{aligned}$$

where K is a positive quantity, as $E(r_1) = E(r_2)$ and $f_1(0,H) > w$.

Therefore

$$\begin{aligned}
\frac{d}{da}\,[E\{U(Y)\}]\Big|_{a=0} &= KE\{U'(nwr_2)\} + E\{wr_2\}\,E\{U'(nwr_2)\} \\
&\quad -E\{wr_2 U'(nwr_2)\} \\
&= KE\{U'(nwr_2)\} - \mathrm{Cov}\{wr_2, U'(nwr_2)\} \\
&> 0
\end{aligned}$$

if $U''(Y) < 0$, since the Pearsonian correlation coefficient between any monotone decreasing function and its argument is negative.

Following a similar procedure, we can establish that

$$\frac{d}{da} [E\{U(Y)\}]\Big|_{a=n} < 0$$

This result is analogous to the general result in portfolio theory which states that a risk-averse investor will always hold positive amounts of each asset if all assets have equal expected returns and are independent. A further portfolio result due to Samuelson[12] is that if any investment has a mean return at least as large as that of any other investments, it must enter positively in the optimal portfolio. The analogue of this result in our context is stated below as proposition II which can be easily verified.

<u>Proposition II</u>

If r_1 and r_2 are independently distributed with finite variances, then (1) if $E(r_1) \geqq E(r_2)$, there will be at least one person on the farm for some part of the year and (2) if $E(r_1) \leqq E(r_2)$, at least one person will be sent to the city for some part of the year.

In the context of a model of our type the implications of different public policies can be best analysed in terms of comparative statics. This analysis can be meaningfully conducted only in terms of the properties of the Arrow-Pratt risk-aversion functions. But unfortunately the model as formulated above does not yield any mathematically tractable definitions of such functions. One simplification which enables us to proceed further is to assume that the utility function is additively separable in Y_1 and Y_2. That is

$$U(Y) = U_1(Y_1) + U_2(Y_2)$$

where both U_1 and U_2 are assumed to be twice continuously differentiable with positive and diminishing marginal utilities, thus guaranteeing risk-aversion and a diminishing marginal rate of substitution between rural and urban income prospects. Equations (5) and (5') become

$$E[U_1'(Y_1)f_1r_1] - E[U_2'(Y_2)wr_2] = 0$$

and

$$\frac{f_1}{w} = \frac{E[U_2'(Y_2)r_2]}{E[U_1'(Y_1)r_1]}$$

respectively.

The second order condition becomes

$$E[U_1''(Y_1)(f_{11}r_1)^2 + U_1'(Y_1)f_{11}r_1] + E[U_2''(Y_2)(wr_2)^2] < 0$$

Concavity of U_1, U_2 and f always assure this condition. The Arrow-Pratt risk-aversion functions can be defined separately for U_1 and U_2 and the required comparative statics can be worked out. But the above simplification appears to be an extreme one and we do not have sufficient grounds to justify it. Rather we will restrict to uncertainty in one source of income at a time in the following sections.

III.3. Uncertain Agricultural Income and Peasant Migration

In this section we treat agricultural income as uncertain and urban income for the migrant as certain. Existence of such urban income, either subjectively or in some objective sense, may be questioned on grounds of realism. Once we explicitly recognize the possibility of earning some income, however meager it may be, by joining the urban 'traditional sector' this is not a totally unwarranted assumption. Moreover, the present formulation automatically answers an unanswered question in the Harris-Todaro literature, namely, how the unemployed migrants live in the city without any earnings! But the basic defense of the assumption is an analytical one; we wish to study the household decision regarding migration when it perceives that income from migration is relatively secure compared to income from farming.[13] A similar argument is made in portfolio theory where usually cash is treated as a secure asset.

The definitions and assumptions of section 2 are strictly followed here except that the household income from job in the city becomes

$$Y_2 = (n-a)w\mu_2 \tag{7}$$

where $0 < \mu_2 < 1$. Note that here we substitute the expected value of the random income of section III.2 to get the certain urban income. Total household income is given by

$$Y = f(a,H)r_1 + (n-a)w\mu_2 \tag{8}$$

Household maximizes its expected utility of income by the choice of 'a'. The corresponding first and second order conditions are given by

$$E[U'(Y)\{f_1r_1 - w\mu_2\}] = 0 \tag{9}$$

and

$$D = E[U''(Y)\{f_1r_1 - w\mu_2\}^2 + U'(Y)f_{11}r_1] < 0 \tag{10}$$

respectively.

It is clear that (10) will be always satisfied if $U''(Y) < 0$ and $f_{11} < 0$. Also, note that if the household is risk-averse, that is if $U''(Y) < 0$, then $f_{11} < 0$ is not a necessary condition for second order condition to be satisfied. For the subsequent analysis we assume that (10) is always satisfied. Equation (9) can be rearranged to get

$$\frac{f_1}{w\mu_2} = \frac{E[U'(Y)]}{E[U'(Y)r_1]} \tag{9'}$$

Equation (9') has the familiar interpretation, that is, equalization of the marginal rate of expected substitution and the ratio of marginal products of labor in the two occupations.

A natural question is: What is the optimum 'a' under uncertainty compared to the case where the weather index is known with certainty to be equal to μ_1, the mean of r_1? Obviously the allocation rule under certainty is given by

$$f_1\mu_1 = w\mu_2 \tag{11}$$

Equation (9) can be written as

$$f_1E[U'(Y)r_1] = w\mu_2E[U'(Y)]$$

Subtracting $f_1\mu_1E[U'(Y)]$ on both sides of this equation

$$f_1E[U'(Y)(r_1-\mu_1] = (w\mu_2-f_1\mu_1)E[U'(Y)] \tag{12}$$

Now,

$$Y = fr_1 + (n-a)w\mu_2$$

Therefore

$$E(Y) = f\mu_1 + (n-a)w\mu_2$$

which implies that

$$Y = E(Y) + f(r_1-\mu_1)$$

If the household is risk-averse, that is if $U''(Y) < 0$, then $U'(Y) \lesseqgtr U'[E(Y)]$ if $r_1 \gtreqless \mu_1$. It immediately follows that $U'(Y)(r_1-\mu_1) \lesseqgtr U'[E(Y)](r_1-\mu_1)$ for $r_1 \gtreqless \mu_1$. Further, it can be easily shown that this inequality holds for

$r_1 < \mu_1$ also.[14] Therefore $E[U'(Y)(r_1-\mu_1)] \stackrel{<}{=} U'[E(Y)]$ $E(r_1-\mu_1)$.

But the right-hand expression is zero as $E(r_1) = \mu_1$.

Hence

$$E[U'(Y)(r_1-\mu_1)] \stackrel{<}{=} 0 \qquad (13)$$

Therefore

$$f_1 E[U'(Y)(r_1-\mu_1)] \stackrel{<}{=} 0$$

From (12) it follows that

$$[w\mu_2 - f_1\mu_1]E[U'(Y)] \stackrel{<}{=} 0$$

Since U'(Y) is always positive, this implies

$$f_1\mu_1 \stackrel{>}{=} w\mu_2 \qquad (14)$$

It immediately follows from the concavity of f that as a result of income uncertainty in agriculture, the equilibrium corresponds to a higher level of migration than under certainty for which the equilibrium condition is given by (11). Even though this result is intuitively apparent, it may be noted that it critically depends on the assumption of risk-aversion. Further, it can be easily shown that if the household has risk-preference, then equilibrium level of migration will be lower under uncertainty than under certainty and finally, if the household is risk-neutral, then the equilibrium level of migration is the same in both cases.

III.3.1. Household Response to Marginal Impacts on Uncertainty

Here we are interested in marginal changes of uncertainty, that is, changes in the moments of the distribution of r_1 on the behavior of the household. Following the Rothschild Stiglitz[15] concept of change in risk, we define a marginal change in risk as a small change in variance of r_1 around a constant mean. Define $r_1^* = \delta r_1 + \theta$, where δ and θ are two shift parameters with initial values 1 and 0 respectively. In order to restore mean, we should have $dE(\delta r_1 + \theta) = 0$, which implies

$$\frac{d\theta}{d\delta} = -E(r_1) = -\mu_1 \qquad (15)$$

The household income becomes

$$Y = f(\delta r_1 + \theta) + (n-a)w\mu_2$$

The first order condition for maximum expected household utility is given by

$$E[U'(Y)\{f_1(\delta r_1 + \theta) - w\mu_2\}] = 0 \qquad (16)$$

By implicitly differentiating (16) with respect to δ, evaluating the results at $\delta = 1$ and $\theta = 0$ and using (15), we get

$$\frac{\partial a}{\partial \delta} = -\frac{f}{D} E[U''(Y)(r_1-\mu_1)\{f_1 r_1 - w\mu_2\}] - \frac{f_1}{D} E[U'(Y)(r_1-\mu_1)]$$

$$= \frac{f}{D} E[R_A(Y) U'(Y)(r_1-\mu_1)\{f_1r_1-w\mu_2\}] - \frac{f_1}{D} E[U'(Y)(r_1-\mu_1)]$$

$$= \frac{f}{D} \text{cov}[R_A(r_1-\mu_1),\ U'(Y)\{f_1r_1-w\mu_2\}] - \frac{f_1}{D} E[U'(Y)(r_1-\mu_1)]$$

from (16), where $R_A(Y)$ is the Arrow-Pratt absolute risk-aversion function defined as $R_A(Y) = \frac{-U''(Y)}{U'(Y)}$.

Now, the second term is negative as $E[U'(Y)(r_1-\mu_1)] \leq 0$, by (13) and D is negative by (10). The first term will be negative if covariance is positive. But $U'(Y)\{f_1r_1-w\mu_2\}$ is positively monotone with respect to $E[U'(Y)\{f_1r_1-w\mu_2\}] = 0$. If R_A is constant, $R_A(r_1-\mu_1)$ is is monotone increasing. By applying a result from the theory of Generalized Correlation[16] we can see that the covariance is positive. However, if R_A is increasing or decreasing, then $R_A(r_1-\mu_1)$ is, in general, neither monotone increasing nor decreasing and as such the sign of covariance is indeterminate. That is, if the household behavior is characterized by constant absolute risk-aversion, then increased (decreased) riskiness in the distribution of weather without changing its mean will increase (decrease) migration. In that case, public policies designed to provide improved irrigation and flood control, for example, even if they do not increase the productivity of land, will reduce migration by reducing the riskiness of farming.

Next, we consider a shift in the mean of the distribution of r_1 without changing its variance. Following Sandmo [1971, p. 69] we define $r_1^* = r_1 + \theta$, with 0 as the initial value of θ. Correspondingly the household income becomes

$$Y = f(r_1 + \theta) + (n - a)w\mu_2$$

and the first order condition for an interior maximum is given by

$$E[U'(Y)\{f_1(r_1+\theta) - w\mu_2\}] = 0 \qquad (17)$$

Implicit differentiation of (17) with respect to θ and setting $\theta = 0$ yields

$$\frac{\partial a}{\partial \theta} = -\frac{f}{D} E[U''(Y)\{f_1 r_1 - w\mu_2\}] - \frac{f_1}{D} E[U'(Y)]$$

$$= \frac{f}{D} \text{Cov}[R_A, U'(Y)\{f_1 r_1 - w\mu_2\}] - \frac{f_1}{D} E[U'(Y)]$$

The second term is unambiguously positive. The first term will be positive if covariance is negative. If R_A is non-increasing, the covariance can be shown to be non-positive so that the first term is non-negative. Similarly if R_A is increasing the first term becomes negative. Hence we can conclude that $\frac{\partial a}{\partial \theta}$ is positive if the household's absolute risk-aversion is non-increasing and positive or negative if it is increasing depending on the relative strengths of the two terms, the former representing income effect and the latter substitution effect respectively.[17] One can consider improved farming techniques and factors like high-yielding seeds and modern fertilizers as equivalent to rightward shift in the distribution of r_1.

It may be interesting to see how a household responds to marginal impacts on uncertainty if its behavior is characterized by risk-neutrality. From the foregoing analysis we can easily deduce that a mean-preserving change in variance will have no effect on migration. But in the case of a risk-preserving shift in the distribution of the random variable, a risk-neutral household behaves just like a household with non-increasing absolute risk-aversion.

A shortcoming of our analysis is that we cannot evaluate a policy which affects both the riskiness and mean of the distribution of the random variable simultaneously. Indeed, many public policies may have such dual effects. However, the economic theory of uncertainty has not yet developed tools to handle such situations.

III.3.2. Household Size and Migration

Certain institutions like joint families[18] are gradually disappearing from peasant societies. Also the impacts of family planning programs and education are currently being felt by many such societies. The net results of all these changes may be a reduction of the size of the household. Here we analyse the impacts of such reduction on migration. Implicit differentiation of (9) with respect to n yields

$$\frac{\partial a}{\partial n} = \frac{-w\mu_2}{D} E[U''(Y)\{f_1 r_1 - w\mu_2\}]$$

$$= \frac{w\mu_2}{D} \mathrm{Cov}[R_A, U'(Y)\{f_1 r_1 - w\mu_2\}]$$

by (9). Assuming that the household is risk-averse, we have three possibilities: (a) R_A decreasing, implying that the covariance is negative so that $\frac{\partial a}{\partial n} > 0$. That is, under decreasing absolute risk-aversion, as the household size decreases so does the number of persons working on the farm. But it is not clear whether migration will increase, remain constant or decrease which depends on whether $\frac{\partial a}{\partial n} \gtreqless 1$. (b) R_A constant, which makes the covariance vanish so that $\frac{\partial a}{\partial n} = 0$. That is, there is no change in the farm labor corresponding to a change in the household size. It implies that the full change will be reflected in reduced migration. (c) R_A increasing, implying that covariance is positive and hence $\frac{\partial a}{\partial n} < 0$. Here reduction in household size leads to an increase in farm labor. It implies that any reduction in household size will be more than compensated by reduced migration.

III.8.3. Farm Size and Migration

In most peasant societies the typical family farm is very small. Moreover, in most tropical agriculture each generation of peasant households inherits a farm less than half the size of that of its immediate predesesor due to unprecedented population growth. Here we analyse the implications of the farm-size reduction on migration. Differentiation of (9) with respect to H yields

$$\frac{\partial a}{\partial H} = -\frac{1}{D}E[U''(Y)f_2 r_1\{f_1 r_1 - w\mu_2\} + f_{12}\ U'(Y)r_1] \qquad (18)$$

where $f_2 = \frac{\partial f}{\partial H}$ and $f_{12} = \frac{\partial f_1}{\partial H}$. Obviously f_2 is positive, and it is reasonable to assume that f_{12} is also positive. Using the definition of Y, (18) can be further simplified to get

$$\frac{\partial a}{\partial H} = \frac{f_2}{D}\,\mathrm{Cov}[R_R,\ U'(Y)\ \{f_1 r_1 - w\mu_2\}] - \frac{f_2(n-a)w\mu_2}{fD}$$

$$\mathrm{Cov}[R_A,\ U'(Y)\ \{f_1 r_1 - w\mu_2\}] - \frac{f_{12}}{D}\,E[U'(Y)r_1]$$

where $R_R(Y)$ is the Arrow-Pratt relative risk-aversion function defined as $R_R(Y) = \frac{-U''(Y)Y}{U'(Y)}$. If the household is risk-neutral, the first two terms vanish and since the last term is always positive, $\frac{\partial a}{\partial H} > 0$. However, if the household is risk-averse, the first term is positive, zero or negative depending on whether R_R is decreasing, constant, or increasing. But consistent with these possibilities the only assumption regarding absolute risk-aversion is that it is decreasing and in that case the second term becomes negative. Hence in general $\frac{\partial a}{\partial H}$ is indeterminate in sign if the household is risk-averse. As argued elsewhere, risk-neutrality may be a reasonable behavioral assumption for richer farmers. As such land reform measures may induce the richer farmers to migrate to cities. However, it is less likely that they may join the urban 'murky' sector.

III.3.4. Change in Urban Earnings and Migration

A change in urban earnings may be due to either a change in the maximum wage w or a change in the fraction μ_2 of it earned by a migrant.[19] The corresponding comparative static result is given by

$$\frac{\partial a}{\partial w\mu_2} = \frac{(n-a)}{D} \operatorname{Cov}[R_A, U'(Y)\{f_1 r_1 - w\mu_2\}] + \frac{1}{D} E[U'(Y)] \qquad (19)$$

If the household is risk-neutral, the first term in (19) vanishes. But, since the second term is always negative, $\frac{\partial a}{\partial w\mu_2} < 0$. That is, a marginal increase in urban earnings will increase migration. The same conclusion can be arrived at even if the household is risk-averse but absolute risk-aversion is non-decreasing, as in this case the first term becomes non-positive. But if the household behavior is characterized by decreasing absolute risk-aversion, then the first term of (19) becomes positive and hence the sign of $\frac{\partial a}{\partial w\mu_2}$ will depend on the relative magnitudes of the two terms, the former representing income effect and the latter, substitution effect respectively.

III.3.5. Income Tax and Migration

As explained in chapter II, income tax plays only a minor role in most developing countries, either as a source of government revenue or as a tool of income distribution. Another feature is its selective nature. In many of these countries there is some sort of urban income taxation but there is no similar tax on rural incomes. On horizontal equity grounds this differential treatment can be objected to. But extension of income tax to agriculture is usually resisted on grounds that this may adversely affect agricultural production and may make rural living less attractive and hence induce more people to migrate. But these objections need not necessarily be true if uncertainty in agricultural output is explicitly taken into account.

Here we consider the effects of marginal changes in income tax (or introduction of income tax) on three types of incomes separately, namely (1) the entire household income (2) urban income alone and (3) rural income alone. Also we consider two types of income taxes separately: (a) proportional income tax and (b) progressive income tax. For the purpose of the following analysis we assume that the tax revenue is spent by the government in a non-distortionary manner. Also, we are fully aware of the practical difficulties involved in the implementation of sophisticated income taxation. As indicated in chapter II, a workable scheme suitable to the particular country's socio-political institutions should be devised.

(a) Proportional Income Tax

(1) Tax on entire household income: The after tax income is given by

$$Y = \{fr_1 + (n-a)\ w\mu_2\}(1-t) \tag{20}$$

where t is the proportional tax rate. Implicitly differentiating the corresponding first order condition and evaluating the derivatives at t = 0, we get

$$\frac{\partial a}{\partial t} = \frac{1}{D} E[U''(Y)Y\{f_1 r_1 - w\mu_2\}]$$

$$= -\frac{1}{D} \mathrm{Cov}\ [R_R,\ U'(Y)\ \{f_1 r_I - w\mu_2\}]$$

It is easy to see that if the household has increasing relative risk-aversion, then $\frac{\partial a}{\partial t}$ is positive, implying that a marginal increase in tax rate reduces migration. On the other hand, if the household is risk-neutral or risk-averse and relative risk-aversion is constant, then marginal increase in tax rate has no effect on migration. And finally, if it has decreasing relative risk-aversion, a marginal increase in proportional income tax rate will increase migration. An intuitive explanation for these conclusions is as follows. A marginal increase in proportional income tax on the entire household income is equivalent to a proportional reduction in income from both sources. A household with increasing relative risk-aversion reacts to this by increasing the proportion of its labor force engaged in the risky venture, that is, farming. Similar explanations can be given for the cases of constant and decreasing relative risk-aversion also.

(2) Tax on Urban Income Alone: The after-tax income of the household is given by

$$Y = fr_1 + (n-a)w\mu_2(1-t) \tag{21}$$

Proceeding as before, we get

$$\frac{\partial a}{\partial t} = \frac{-(n-a)w\mu_2}{D} \operatorname{Cov}[R_A, U'(Y)\{f_1 r_1 - w\mu_2\}]$$

$$- \frac{w\mu_2}{D} E[U'(Y)]$$

The second term is unambiguously positive. Covariance is positive, zero or negative depending on whether household has increasing, constant or decreasing absolute risk-aversion. Hence we can conclude that if the household has non-decreasing absolute risk-aversion, then an increase (decrease) in tax rate on urban income decreases (increases) migration. If we make the more reasonable assumption of decreasing R_A, then the result depends on the relative magnitudes of income and substitution effects, the former being negative and the latter positive.

(3) Tax on Farm Income Alone: The after tax income can be written as

$$Y = fr_1(1-t) + (n-a)w\mu_2 \tag{22}$$

We can get

$$\frac{\partial a}{\partial t} = -\frac{1}{D}\,\text{Cov}\,[R_R, U'(Y)\,\{f_1 r_1 - w\mu_2\}]$$

$$+ \frac{(n-a)}{D}\,w\mu_2\text{Cov}[R_A, U'(Y)\,\{f_1 r_1 - w\mu_2\}]$$

$$+ \frac{f_1}{D}\,E[U'(Y)r_1]$$

The third term is unambiguously negative. If the household is risk-averse, in general, the sign of $\frac{\partial a}{\partial t}$ is indeterminate. If it has increasing relative risk-aversion and decreasing absolute risk-aversion, for example, then the first two terms are positive. Thus it is clear that with uncertainty in agricultural income, the effect of farm income taxation need not be increased migration.

(b) Progressive Income Tax

Here we consider a proportional income tax with an exemption level, which is equivalent to a linear progressive tax with negative income taxation. Let t denote the marginal tax rate and K, the level of exemption.

(1) Tax on Entire Household Income: The after tax income is given by

$$Y = \{fr_1 + (n-a)w\mu_2 - K\}(1-t) + K \tag{23}$$

Totally differentiating the corresponding first order condition with respect to t, evaluating the derivatives at t = 0 and after some simplifications, we get

$$\frac{\partial a}{\partial t} = -\frac{1}{(1-t)D} \mathrm{Cov}[R_R, U'(Y)\{f_1 r_1 - w\mu_2\}$$

$$+ \frac{K}{(1-t)D} \mathrm{Cov}[R_A, U'(Y)\{f_1 r_1 - w\mu_2\}]$$

If R_R is increasing and R_A is decreasing simultaneously, then the first covariance is positive and the second covariance is negative so that both terms are positive and hence $\frac{\partial a}{\partial t} > 0$. If R_R is constant and R_A is decreasing, then also $\frac{\partial a}{\partial t} > 0$. However, if R_R is decreasing and R_A is also decreasing then the sign of $\frac{\partial a}{\partial t}$ depends on the relative magnitudes of the two terms. Finally, if the household is risk-neutral, then $\frac{\partial a}{\partial t} = 0$. Hence we can conclude that under the most reasonable assumptions regarding risk-behavior of the household, a marginal increase in the progressive income tax rate on the entire household income will decrease migration.

To analyse the effect of a marginal change in the exemption level on migration, totally differentiate the first order condition corresponding to equation (23) with respect to K and get

$$\frac{\partial a}{\partial K} = \frac{t}{D} \mathrm{Cov}[R_A, U'(Y)\{H\bar{f}_1 r_1 - w\mu_2\}]$$

It is clear that $\frac{\partial a}{\partial K} \gtreqless 0$ depending on whether $R_A' \lesseqgtr 0$. That means, in the most likely case of decreasing absolute risk-aversion, an increase in the exemption level decreases migration.

(2) Tax on Wage Income Alone: The after-tax income is given by

$$Y = fr_1 + \{(n-a)w\mu_2 - K\}(1-t) + K \tag{24}$$

Proceeding as before, we get

$$\frac{\partial a}{\partial t} = \frac{-\{(n-a)w\mu_2 - K\}}{D} \mathrm{Cov}[R_A, U'(Y)\{f_1 r_1 - w\mu_2\}]$$

$$- \frac{w\mu_2}{D} E[U'(Y)]$$

and

$$\frac{\partial a}{\partial K} = \frac{t}{D} \mathrm{Cov}[R_A, U'(Y)\{f_1 r_1 - w\mu_2(1-t)\}]$$

It can be shown that the sign of $\frac{\partial a}{\partial t}$ is determinate and positive if 1) R_A is non-decreasing or 2) R_A is decreasing and the exemption level is higher than the household's income from urban sector. If R_A is decreasing and the wage income exceeds the exemption level, then the sign of $\frac{\partial a}{\partial t}$ depends on the relative magnitudes of the two terms in the expression for $\frac{\partial a}{\partial t}$, the former representing income effect and the latter, substitution effect. Finally, if the household is risk-neutral, then $\frac{\partial a}{\partial t} > 0$. The expression for $\frac{\partial a}{\partial K}$ is same as that in case (1) and hence the conclusions are identical to that of a tax on the entire income.

(3) Tax on Farm Income Alone: After-tax income of the household is given by

$$Y = \{fr_1 - K\}(1-t) + K + (n-a)w\mu_2 \tag{25}$$

The corresponding comparative static results are:

$$\frac{\partial a}{\partial t} = -\frac{1}{D} \mathrm{Cov}[R_R, U'(Y)\{f_1 r_1 - w\mu_2\}]$$

$$+ \frac{\{K+(n-a)w\mu_2\}}{D} \mathrm{Cov}[R_A, U'(Y)\{f_1 r_1 - w\mu_2\}]$$

$$+ \frac{f_1}{D} E[U'(Y) r_1]$$

and

$$\frac{\partial a}{\partial K} = \frac{t}{D} \mathrm{Cov}[R_A, U'(Y)\{f_1 r_1 (1-t) - w\mu_2\}]$$

Under the most reasonable assumptions of increasing relative and decreasing absolute risk-aversions, $\frac{\partial a}{\partial t}$ becomes indeterminate, as the first two terms become positive and the third term is always negative. The only case in which the sign of $\frac{\partial a}{\partial t}$ is definite is the case of risk-neutrality and then it is negative. The expression for $\frac{\partial a}{\partial K}$ is same as that of earlier cases and hence the same conclusions follow.

A general conclusion of the above discussion is that marginal changes in tax parameters will affect migration decisions of the household. However, the decisions will critically depend on the attitude of the household towards risk-taking and also the relationship between the risk-behavior and the level of the household income. Also, in general, the results are different from those based on deterministic models. For example, under reasonable assumptions, it can be seen that an increase in agricultural income tax rate may actually decrease migration. This result is not surprising. It is an extension of a similar result in the analysis of taxation and risk-taking, namely, increased taxation encouraging risk-taking under very reasonable assumptions on risk-aversion. Since urban income is certain and agriculture is the risky prospect, the analogy would seem to be appropriate.

III.4. Uncertain Urban Income and Peasant Migration

Here, in the Harris-Todaro tradition, we treat rural income as certain and migrant's urban income as uncertain. Let

$$Y_1 = f(a, H) \tag{26}$$

$$Y_2 = (n-a)wr_2 \tag{27}$$

where r_2 is a random variable such that $0 \leq r_2 \leq 1$, $E(r_2) = \mu_2$ and $V(r_2) = \sigma_2^2$, a finite quantity. The urban income varies from 0 to w depending on the realization of the random variable r_2. If one treats w as minimum wage, then r_2 takes only two values, 1 with probability μ_2 and 0 with probability $(1-\mu_2)$. All other definitions and assumptions remain same as in section 2 of this chapter. The total household income is given by

$$Y = f(a, H) + (n-a)wr_2 \tag{28}$$

Assuming that the household chooses 'a' so as to maximize expected utility of income, the first and second order conditions for an interior solution are

$$E[U'(Y)\{f_1 - wr_2\}] = 0 \qquad (29)$$

and

$$E[U''(Y)\{f_1 - wr_2\}^2 + U'(Y)f_{11}] < 0 \qquad (30)$$

respectively. Equation (29) can be rearranged to get

$$\frac{f_1}{w} = \frac{E[U'(Y)r_2]}{E[U'(Y)]} \qquad (30')$$

which has the usual interpretation. The counterpart of Harris-Todaro migration equilibrium for our model is given by

$$f_1 = w\mu_2 \qquad (31)$$

where $\mu_2 = E(r_2)$. One question naturally raised by the introduction of explicit uncertainty in urban income is how does the optimal allocation of labor between farming and job-seeking compare with the Harris-Todaro allocation. Following the procedure established in section 3 of the present chapter, it can be easily shown that if the household is risk-averse, then

$$f_1 \leqq w\mu_2 \qquad (32)$$

This implies that compared to Harris-Todaro result fewer laborers will be going to the city.[20]

In order to analyse the effects of marginal changes in the moments of the distribution of r_2 on migration we follow the technique adopted in section 3.2. Defining $r_2^* = \delta r_2 + \theta$ and imposing the restriction $\frac{d\theta}{d\delta} = -\mu_2$, implicit differentiation of the corresponding first order condition after some simplifications gives

$$\frac{\partial a}{\partial \delta} = \frac{1}{(n-a)wD} \text{Cov}[R_R, U'(Y)\{f_1 - wr_2\}] - \frac{1}{D}\{\frac{f}{(n-a)w} + \mu_2\}$$

$$\text{Cov}[R_A, U'(Y)\{f_1 - wr_2\}] + \frac{w}{D} E[U'(Y)(r_2 - \mu_2)]$$

It can be easily shown that if the household is risk-averse, then $E[U'(Y)(r_2-\mu_2) \leq 0$ and hence the last term is positive. Now, $U'(Y)\{f_1-wr_2\}$ is negatively monotone with respect to $E[U'(Y)\{f_1-wr_2\}] = 0$. Hence if R_R is non-increasing, then the first two terms become non-negative. Thus under the most reasonable risk-behavior on the part of the household, $\frac{\partial a}{\partial \delta}$ becomes positive which implies that a decrease (increase) in the riskiness of urban income increases (decreases) migration. One can think of a number of public policies like minimum wages and assured urban housing and other public goods which have the effect of reducing the riskiness of urban income. All such policies will tend to increase migration.

In a similar manner, defining $r_2^* = r_2 + \theta$ and following the method adopted in section 3.1 of this chapter, we get an expression for the effect on migration of a risk-preserving change in mean of the distribution of r_2 as

$$\frac{\partial a}{\partial \theta} = \frac{(n-a)w}{D} \text{Cov}[R_A, U'(Y)\{f_1 - wr_2\}] + \frac{w}{D} E[U'(Y)]$$

which can easily be shown to be negative if R_A is non-increasing. One can think of a number of public policies which in effect enhance the mean of r_2 and hence induce migration.

As was argued in section III.3.2, the household size may be subject to changes due to public policies like family planning programs and education. We can easily get

$$\frac{\partial a}{\partial n} = \frac{1}{D(n-a)} \text{Cov}[R_R, U'(Y)\{f_1 - wr_2\}]$$

$$- \frac{f}{D(n-a)} \text{Cov}[R_A, U'(Y)\{f_1 - wr_2\}]$$

Under the most reasonable assumptions regarding household behavior, namely increasing R_R and decreasing R_A, the above expression can be clearly seen to be positive. It implies that as household size increases so does the number of people working on the farm. But our model will not make it clear whether migration will increase, remain unchanged or decrease which depends on whether $\frac{\partial a}{\partial n} \lesseqgtr 1$.

As in section 3.3 we can get an expression for the effect of change in farm size on migration as

$$\frac{\partial a}{\partial H} = \frac{f_2}{D} \text{Cov}[R_A, U'(Y)\{f_1 - wr_2\}] - \frac{f_{12}}{D} E[U'(Y)]$$

Making the same set of assumptions as in section III.3.3, the second term is unambiguously positive. First term is positive, zero or negative depending on whether $R_A' \gtreqless 0$.

Following the procedure of section III.3.5, the effects of proportional and progressive income tax on various types of incomes can be analysed. Below we summarize the effects of proportional income tax on migration.

(1) Tax on entire household income:

$$\frac{\partial a}{\partial t} = -\frac{1}{(1-t)D} \text{Cov}[R_R, U'(Y)\{f_1 - wr_2\}] \lesseqgtr 0 \text{ depending}$$

on whether $R_R' \gtreqless 0$.

(2) Tax on farm income alone:

$$\frac{\partial a}{\partial t} = -\frac{1}{D} \text{Cov}[R_A, U'(Y)\{f_1 - wr_2\}] + \frac{f_1}{D} E[U'(Y)] \lesseqgtr 0$$

if $R_A' \geqq 0$ and in determinate if $R_A' < 0$.

(3) Tax on wage income alone:

$$\frac{\partial a}{\partial t} = -\frac{1}{D} \text{Cov}[R_A, U'(Y)\{f_1 - wr_2\}] + \frac{f_1}{D}$$

$$\text{Cov}[R_A, U'(Y)\{f_1 - wr_2\}] - \frac{w}{D} E[U'(Y) r_2] > 0$$

if $U''(Y) = 0$ and depends on the relative magnitudes of the three terms otherwise.

In a similar manner we can analyse the effect of marginal changes in the progressive tax rate and level of exemption on different incomes.

Also a comparison between the results in section III.3 and the present section clearly brings out the policy implications on migration of the relative security of rural versus urban incomes.

III.5. Concluding Remarks

The discussions in the foregoing sections are based on a rather simplified model of rural-urban migration. Since our basic concern is to explore the implications of uncertainty in agricultural production on migration, even this simplified framework may be justified as a first step. Moreover, we are able to bring forth certain qualitative results having obvious policy significance. Perhaps the most significant policy conclusion emerging from the present analysis is the great difficulty of substantially reducing migration without a concentrated effort at making rural life more attractive in the sense of reducing uncertainty in farm income. Unless the risk of farming is substantially reduced or transferred from the farmer through a process of social risk-taking, the peasants will continue to move to the urban areas even if there is no institutionally fixed high minimum wage. Also, our analysis reinforces the original Harris-Todaro conclusion that economist's standard theoretical policy prescription of generating urban employment opportunities through the use of 'shadow prices' implemented by means of wage subsidies or direct government hiring might, in fact, exacerbate the problem of urban unemployment and under-employment. As Todaro [1976, p. 222] put it: There would thus appear to be no strictly urban solution to the urban unemployment problem. Rural development is essential.

However, our conclusions critically depend on the characterization of risk-behavior of the rural households. The center-piece of our analysis is the assumption of risk-aversion. But, in many cases, for definite qualitative results we have to assume specific functional forms for the risk-aversion functions. In most cases the validity of our conclusions critically depends on the reliability of the implied assumptions which need empirical verification.

Finally, our model calls for modifications and extensions in at least three directions. An obvious modification is to allow for labor-leisure choice, especially in the rural sector because in most peasant societies farming is more of a way of life than just a means of livelihood. Secondly, the partial equilibrium framework employed here limits the scope of any discussion of welfare implications of the various public policies and a natural extension may be to develop the analysis in a two-sector framework. And finally, the very nature of agriculture in the present-day developing countries require a dynamic framework for a more useful discussion of any public policies.

Footnotes

1. There is a vast literature in this area. Some important examples are Nurkse [1953], Lewis [1954], Rosenstein-Rodan [1957], Ranis and Fei [1961] and Sen [1966].

2. The pioneering work in this area is by Jorgenson; See Jorgenson [1961, 1967].

3. For specific results and the conditions under which they are derived, see Todaro [1976], p. 216-20, for example.

4. Some examples are Stiglitz [1969, 1974], Bhagwati and Srinivasan [1974, 1975], Fields [1975], Bhatia and Sharir [1976], Todaro [1976] and Blomqvist [1977].

5. Here we identify rural income with farm income. Since the rural economy is built around agriculture, a bad crop means poor income to all rural people except perhaps to the money lenders, even though they may have to suffer due to default risk.

6. Bhatia and Sharir [1976] is an example.

7. A typical migrant is not a solitary fortune-hunter who gets lost in the city. His purpose is mainly to augment the household income and as such migration is essentially a household decision, the risk of which is collectively borne by the household.

8. This may be a rather restrictive assumption. It can be justified either (1) by assuming that all peasant households are identical or (2) by arguing that the rural labor demand is a random variable with high positive correlation with the weather uncertainty.

9. This may be a strong assumption as group preferences may not always satisfy the transitivity axiom required for the existence of a utility function. It is possible, therefore, that this approach implicitly assumes that the household's reactions to changes in its environment are more predictable and stable than they really are. However, we can agree that in most households decisions are essentially made by the head of the household and they are made in the best interest of the entire family and that in most households preferences are sufficiently similar to justify the existence of a group preference function.

10. One can argue that r_1 and r_2 are positively correlated. For example, a bad harvest due to bad weather conditions may adversely affect job prospects in urban areas with a certain time-lag. However, in a short-run model like ours, independence of r_1 and r_2 may be a reasonable assumption.

11. Our treatment of 'a' as a continuous variable can be defended by redefining n and a appropriately. For example, n can be defined as the total number of man-weeks or man-days at the disposal of the household and n-a as the total man-weeks or man-days spent in the city. It is a usual practice among peasants to migrate to cities during the slack seasons and to return to farms during planting and harvesting seasons.

12. Samuelson [1967], pp. 5-6.

13. Consider, for example, the case of a villager coming to Calcutta where he earns daily a couple of rupees by carrying luggage whereas back at home there is a fifty per cent chance of his entire rice crop being destroyed by floods.

14. When $r_1 < \mu_1$, $Y < E(Y)$ so that $U'(Y) > U'[E(Y)]$. Therefore $U'(Y)(r_1-\mu_1) \leq U'[E(Y)](r_1-\mu_1)$ for $r_1 < \mu_1$ also.

15. See Rothschild and Stiglitz [1970]. For details, see Appendix A.4.

16. See Scheffman [1974], pp. 278-79. Also see footnote 16 of chapter II for details.

17. This can be easily verified as follows: Totally differentiate $E[U\{f(r_1+\theta) + (r-a)w\mu_2\}] = c$, a constant. The result can be expressed as $\frac{dx}{d\theta}$, where x stands for any one of the parameters in the system. Then, totally differentiate the first order condition viz $E[U'(Y)\{f_1(r_1+\theta)-w\mu_2\}] = 0$. Simplifying the resulting expression and using the result $\frac{dx}{d\theta}$, we get $\frac{\partial a}{\partial \theta}\Big|_{\overline{U}} = -\frac{f_1 E[U'(Y)]}{D}$, which is obviously the second term in the expression for $\frac{\partial a}{\partial \theta}$ in the text. It immediately follows that the first term of the expression stands for income effect.

18. Joint family system used to be very common in various parts of India. According to this, several related nuclear families live together and operate a large joint farm. This can be considered as an ideal form of cooperative or mutual enterprise except that membership is restricted to close relatives. Sharing of risks used to be one of the primary goals of this arrangement. A common criticism of this institution is that it reduces incentives to hard-work and initiative.

19. Also this can come about due to specific public policies like improving the living conditions of the poor in cities, providing better public transportation, health programs and other public amenities.

20. Bhatia and Sharir [Ibid] reached essentially the same conclusion using a different model.

CHAPTER IV

A THEORY OF AGRICULTURAL INSURANCE

IV.1. Introduction

A major role played by insurance programs includes the indemnification of risk-averse individuals who might be adversely affected by natural phenomena of a probabilistic nature. By pooling the individual risks, insurance leads to Pareto-preferred states. Just like the stock markets, insurance, by offering the possibility of shifting risks, also enables individuals to engage in risky activities which they would not otherwise undertake. To quote Arrow:[1] I may well hesitate to erect a building out of my own resources if I have to stand the risk of its burning down; but I would build if the building can be insured against fire. As was discussed in chapter I, agriculture is one sector of any economy where uncertainty due to natural hazards has an important effect on decision making. But, unlike most other risks, agriculture is considered a bad risk and insurance is seldom provided by the market. Even in advanced market economies, all-risk crop insurance contracts are offered only by public sector agencies. In developing countries, where the need for crop insurance protection is even greater,[2] practically there exists no such mechanism.

The purpose of this chapter is to develop a theory of crop insurance within a general equilibrium framework. We begin by clarifying certain conceptual and analytical issues which demonstrate the need for a separate theoretic analysis of crop insurance. Then, we provide certain theoretical justifications for the non-existence of competitive crop insurance markets. And finally, we develop a theoretical model of public crop insurance and analyse its properties.

IV.2. Salient Features of Agricultural Risks

A standard insurance situation is one where the insurance agency has reasonably objective knowledge about the risk involved, a large number of similarly exposed individuals are involved, the incidence of risk is independently distributed over individuals and the individuals can in no way influence the nature and occurrence of the risky incident as well as the amount of indemnity received, once they buy a policy. In such an idealized context insurance contracts will be traded like any other contingent commodity and the premium will be determined like any other price by the forces of demand and supply.

The risk associated with crop failure is perhaps one situation where none of the above criteria is satisfied.

Any objective information regarding crop failure has to come from time series data. These data, by farm or homogeneous region, are hard to gather - especially in developing countries. The farmers may be far from similarly exposed to riskiness of crop failure. The individual farmers themselves may have fair knowledge about their own risk position. But the insurance agencies may not have and as such they cannot distinguish among customers. This usually leads to the problem of 'adverse selection'; that is, only high-risk farmers will buy insurance and hence insurance companies will incur heavy losses.[3]

As Spence and Zeckhauser [1971, pp. 380] noted, there should be substantial independence in the incidence of the random event for the existence of insurance contracts. If this condition is not satisfied, the working of the law of large numbers on which premium and indemnity are based breaks down. Unlike most other insurance situations, in the case of crop insurance the incidence of risk is not independently distributed among the individuals. Good or bad weather conditions may have similar effects on large number of farmers in adjoining areas. For example, a flood may wipe out the crop of all farmers in a region. Only insurance agencies covering greatly varying agro-climatic areas can hope to face up to a situation like this.[4]

A very important problem facing risk-shifting in general and insurance in particular is 'moral hazard'. The insurance policy might itself change incentives and therefore the probabilities upon which the insurance company relied upon. In other words, moral hazard is the tendency of an insured individual to take less care in preventing loss than an uninsured counterpart. In this case the insurance is bearing socially unnecessary risks. It is in this context that Arrow [1971, pp. 220] stated that if the amount of insurance payment is in any way dependent on a decision of the insured as well as on a state of nature, then the effect is very much the same as that of any excise tax and optimality will not be achieved either by the competitive system or by an attempt by the government to simulate a perfectly competitive system. In the case of crop insurance it may be fair to say that the individuals have no control over the state of nature. But depending on the nature of the contract, the individual can affect the amount of indemnity.

In section IV.3 we attempt a formal proof that a competitive crop insurance market may not exist at all.

IV.3. Competitive Crop Insurance Market

Consider a peasant economy composed of a large number of identical farmers owning 'A_0' units of land each. A typical farmer's income measured in units of the homogeneous agricultural output is given by:

$$Z = KA^{\alpha}n + r(A_0 - A) \qquad (1)$$

where K is a positive scale factor, A is the area under cultivation, α is the output elasticity of land, n is a positive random variable representing the uncertainty in agricultural output due to natural hazards and r is the secure income per unit area of land rented out.[5] Further, we assume that $r > 0$, $0 < \alpha < 1$ and n is distributed with a probability density function $dP(n)$ such that $E(n) = \bar{n}$ and $V(n) = \sigma^2 < \alpha$.

In the absence of crop insurance, the farmer chooses the area to be cultivated so as to maximize the expected utility of his income. We assume that his attitude towards risk can be summarized by a Von Neumann-Morgenstern utility function. Thus the mathematical formulation of individual farmer's problem is:

$$\underset{[A]}{\text{Max}}\ E[U\{KA^{\alpha}n + r(A_0 - A)\}]$$

The first order condition for an interior extremum is

$$E[U'(Z)(K\alpha A^{\alpha-1}n - r)] = 0 \qquad (2)$$

Equation (2) states, in effect, that $E[U'(Z)\frac{\partial Z}{\partial A}] = 0$ which has a straightforward interpretation. The second order sufficiency condition for expected utility maximum is given by

$$E[U''(Z)(K\alpha A^{\alpha-1}n - r)^2 + U'(Z)K\alpha(\alpha-1)A^{\alpha-2}n] < 0 \qquad (3)$$

It is clear that if the farmer is risk-averse, that is, $U''(Z) < 0$ and $\alpha < 1$, then the second order condition will always be satisfied.

In order to focus on the insurance market, let us make the simplifying assumption that there are only two states of nature. State one occurs with probability (1-p) and n takes the value n_1; state two occurs with probability p and n takes the value n_2. The farmer's incomes in the two states are given by

$$Z_1 = KA^{\alpha}n_1+r(A_0-A) \quad \text{with probability } (1-p) \tag{4a}$$

$$Z_2 = KA^{\alpha}n_2+r(A_0-A) \quad \text{with probability } p \tag{4b}$$

Let $n_1 > n_2$. Assume that competitive insurance firms exist which offer insurance coverage of $(KA^{\alpha}n_1-KA^{\alpha}n_2)$ at a premium of q per unit area. If the coverage ratio is 'a', then the premium per unit area will be aq.[6] With insurance, the farmer's incomes in the two states are given by

$$Y_1 = KA^{\alpha}n_1+r(A_0-A)-aqA \tag{5a}$$

$$Y_2 = KA^{\alpha}n_2+r(A_0-A) + a(KA^{\alpha}n_1-KA^{\alpha}n_2)-aqA \tag{5b}$$

For further simplicity, we let $n_1 = 1$ and $n_2 = 0$. Therefore

$$Y_1 = KA^{\alpha}+r(A_0-A)-aqA \tag{6a}$$

$$Y_2 = aKA^{\alpha}+r(A_0-A)-aqA \tag{6b}$$

Expected utility of income of the farmer is given by

$$V = (1-p)U(Y_1) + pU(Y_2) \tag{7}$$

Assuming that insurance firms are risk neutral,[7] a typical firm's expected profit is given by

$$\pi = (1-p)aqA - p(aKA^{\alpha}-aqA) \quad (8a)$$

or

$$\pi = aqA-paKA^{\alpha} \quad (8b)$$

A competitive solution can be defined either as

(a) $\underset{[a,A]}{\text{Max}}$ V subject to $\pi = 0$

or

(b) $\underset{[q]}{\text{Max}}$ π subject to V = constant.

We use the first definition. That is

$$\underset{[a,A]}{\text{Max}}\ V = (1-p)U(Y_1) + pU(Y_2)$$

subject to

$$\pi = aqA-paKA^{\alpha} = 0 \Rightarrow q = pKA^{\alpha-1}$$

That is

$$\underset{[a,A]}{\text{Max}}\ V = (1-p)U\{KA^{\alpha}+r(A_0-A) - apKA^{\alpha}\}$$
$$+ pU\{aKA^{\alpha}+r(A_0-A) - apKA^{\alpha}\}$$

The first order conditions for an interior solution are

$$(1-p)U'(Y_1)(-pKA^{\alpha}) + pU'(Y_2)(KA^{\alpha}-pKA^{\alpha}) = 0 \quad (9a)$$

$$(1-p)U'(Y_1)(K\alpha A^{\alpha-1}-r-apK\alpha A^{\alpha-1})$$

$$+ pU'(Y_2)(aK\alpha A^{\alpha-1}-r-apK\alpha A^{\alpha-1}) = 0 \quad (9b)$$

Equation (9a) implies that optimal 'a', a* is such that $U'(Y_1) = U'(Y_2)$. Since sufficiency conditions require that $U''(Y) < 0$, this can be true only if $Y_1 = Y_2 = Y$, which implies that a* = 1. That is, farmer will choose full coverage if insurance is offered at actuarial odds. Similar results are obtained by Mossin [1973, pp. 23-24] and Rothschild and Stiglitz [1976, p. 634] in different contexts.

Now, the second equation becomes

$$(1-p)U'(Y)(K\alpha A^{\alpha-1}-r-pK\alpha A^{\alpha-1})$$

$$+ pU'(Y)(K\alpha A^{\alpha-1}-r-pK\alpha A^{\alpha-1}) = 0$$

That is

$$(1-p)(K\alpha A^{\alpha-1}-r-pK\alpha A^{\alpha-1}) + p(K\alpha A^{\alpha-1}-r-pK\alpha A^{\alpha-1}) = 0$$

i.e., $K\alpha A^{\alpha-1}-r-pK\alpha A^{\alpha-1} = 0$

i.e., $K\alpha A^{\alpha-1}(1-p) = r$

i.e., $A^{\alpha-1} = \frac{r}{K(1-p)\alpha}$

Therefore

$$A^* = \left[\frac{r}{K(1-p)\alpha}\right]^{\frac{1}{\alpha-1}} \quad (10)$$

and

$$q^* = pKA^{\alpha-1} = \frac{pr}{(1-p)\alpha} \tag{11}$$

Thus we can see that in this simple case of identical farmers there exists a competitive solution where everyone buys complete insurance at actuarial odds. This model also determines the optimal area to be cultivated A^* and the optimal rate of insurance premium q^*.

Imperfect Information: Two Classes of Farmers

The simple case considered above is an exception rather than the rule in most peasant agriculture. Absence of adequate information by the crop insurance firms may be a genuine problem. In general, the cost of collection of such information may be prohibitively high.

Here we assume that farmers belong to two groups (a) high-risk farmers with probability of crop loss p^h; (b) low-risk farmers with probability of crop loss $p^l < p^h$. If the fraction of high-risk farmers is λ, the average probability of crop failure is

$$\bar{p} = \lambda p^h + (1-\lambda) p^l \tag{12}$$

In a situation like this, there can be two types of equilibria: pooling equilibria in which both groups buy the same contract; and separating equilibria in which different groups purchase different contracts.

The nature of imperfect information is as follows. Every farmer knows the group he belongs to, but a typical insurance firm does not have this information. All that the insurance firms know is that some of the farmers are high risk and some are low risk. The farmers are still identical with respect to their tastes, technologies, endowments, and the manner in which nature affects their crop yields. They differ only with respect to the frequencies with which the good and bad states of nature visit them. In the absence of insurance, real incomes of farmers are given by

(high risk)

$$Z_1^h = n_1KA^\alpha + r(A_0 - A) \text{ with prob } (1-p^h) \quad (13a)$$

$$Z_2^h = n_2KA^\alpha + r(A_0 - A) \text{ with prob } p^h \quad (13b)$$

(low risk)

$$Z_1^l = n_1KA^\alpha + r(A_0 - A) \text{ with prob } (1-p^l) \quad (14a)$$

$$Z_2^l = n_2KA^\alpha + r(A_0 - A) \text{ with prob } p^l \quad (14b)$$

Also note that in this case, we assume that the farmer's choice of A has already been made, and this has been done independent of the insurance contract to be chosen. Also, for added simplicity, we assume that the chosen values are $A^h = A^l = A$. The insurance contracts are similar to the ones discussed above. All farmers insure a fraction of $(n_1-n_2)KA^\alpha$ at a certain rate of premium offered by the market. Letting $n_1 = 1$ and $n_2 = 0$, the real incomes after insurance can be written as

(high risk)

$$Y_1^h = KA^\alpha + r(A_0 - A) - a^hq^hA \text{ with prob } (1-p^h) \quad (15a)$$

$$Y_2^h = r(A_0 - A) + a^hKA^\alpha - a^hq^hA \text{ with prob } p^h \quad (15b)$$

$$Y_1^l = KA^\alpha + r(A_0 - A) - a^l q^l A \text{ with prob } (1-p^l) \quad (16a)$$

(low risk)

$$Y_2^l = r(A_0 - A) + a^l KA^\alpha - a^l q^l A \text{ with prob } p^l \quad (16b)$$

The set of market opportunities, that is, the set of all contracts that break even, is given by

$$\pi = \lambda[a^h q^h A - p^h a^h KA^\alpha] + (1-\lambda)[a^l q^l A - p^l a^l KA^\alpha] = 0 \quad (17)$$

Case 1: Pooling Equilibrium

We define a pooling equilibrium as one where everyone buys the same contract, denoted by $(\bar{a}, \bar{q})$ where $\bar{a} = a^h = a^l$ and $\bar{q} = q^h = q^l$. The market opportunities are then simplified into

$$\bar{a}\,\bar{q}\,A - \bar{a}\,\bar{p}\,KA^\alpha = 0 \quad (18)$$

or

$$\bar{q} = \bar{p}\,KA^{\alpha-1} \quad (19)$$

Since A is given, the premium rate is determined by $\bar{p}$. However, it is easy to see that such an equilibrium will not be achieved since utility maximizing farmers choose to buy different amounts of insurance coverage. This is seen as follows. Substituting (19) in the utility functions, the maximizing problem for the high-risk farmers is given by

$$\max_{\{a^h\}} V = (1-p^h)U[KA^\alpha + r(A_0 - A) - a^h\bar{p}KA^\alpha]$$
$$+ p^h U[r(A_0 - A) + a^h KA^\alpha - a^h\bar{p}KA^\alpha]$$

The first order condition is given by

$$\frac{(1-p^h)U'(Y_1)}{p^h U'(Y_2)} = \frac{1-\bar{p}}{\bar{p}} \tag{20}$$

The left hand side can be identified as the marginal rate of substitution between real income of the high-risk farmers in the two states of nature, while the right hand side is the slope of the fair odds line, equation (18), in the (Y_1, Y_2) space. Similarly, for the low-risk farmers, the equilibrium condition is

$$\frac{(1-p^l)U'(Y_1)}{p^l U'(Y_2)} = \frac{1-\bar{p}}{\bar{p}} \tag{21}$$

Notice that Y_1 and Y_2 can be different for the two types of farmers iff $a^h \neq a^l$. Comparing (20) and (21), it is quite obvious that a pooling equilibrium cannot exist in this context, in the sense that both groups of farmers do not demand the same contract. However, one might speculate that a Nash equilibrium[8] could still exist. In a recent paper, Rothschild and Stiglitz [1976], using a model very similar to the present one (that is, with predetermined A), showed that a Nash-type pooling equilibrium does not exist either.

Case 2: Separating Equilibria

As mentioned earlier, a separating equilibrium is one where each type of farmer purchases a separate contract.

The set of contracts that break even for the high-risk type is given by

$$(1-p^h)a^hq^hA - p^h(Ka^hA^\alpha - a^hq^hA) = 0 \tag{22}$$

or

$$q^h = p^hKA^{\alpha-1} \tag{23}$$

The typical individual in high-risk group faces the following problem:

$$\max_{\{a^h\}} V^h = (1-p^h)U[KA^\alpha + r(A_0-A) - a^hp^hKA^\alpha]$$
$$+ p^hU[r(A_0-A) + a^hKA^\alpha - a^hp^hKA^\alpha]$$

The first order condition is given by

$$\frac{(1-p^h)U'(Y_1^h)}{p^hU'(Y_2^h)} = \frac{1-p^h}{p^h} \tag{24}$$

which states that marginal rate of substitution equals the slope of (22) in (Y_1, Y_2) space. Clearly (24) also implies that

$$U'(Y_1^h) = U'(Y_2^h) \tag{25}$$

That is, the most preferred contract by high-risk farmers gives complete insurance.

In an identical manner, it can be seen that the same conclusion holds for low-risk farmers. However, since they face different odds, the level of $Y_1^l = Y_2^l$ would be greater than that for high-risk farmers. But these two contracts do not represent a separating equilibrium simply because if both are offered everyone would buy the latter as it involves higher incomes in both states of nature. This is due to the nature of imperfect information, namely that, insurance companies are unable to distinguish among their customers. Profits will, therefore, be negative and hence the above contracts do not characterise an equilibrium set. However, Rothschild and Stiglitz [1976], in the context of a similar model, pointed out that a separating equilibrium may exist which involves complete insurance by high-risk individuals and incomplete insurance by low-risk individuals. But they also point out that, indeed, such an equilibrium may not exist.[8]

Discussion

It should be pointed out that so far we have assumed A as given, which renders our crop insurance model formally similar to the insurance model considered by Rothschild and Stiglitz. Thus it is not surprising that their results also apply to our case. But it is apparent that these results will be further strengthened if the farmer's choice involved the simultaneous determination of the area to be cultivated also.[9] Further, an important problem in any real world insurance, and crop insurance in particular is 'moral hazard'. As Arrow[10] argued, moral hazard can be considered as a special case of lack of information. For a successful program of crop insurance, continuous monitoring of farmer's behavior from land preparation to harvesting may be needed. Such information-gathering is totally infeasible in a market insurance and thus it adds another dimension to the information problem. Moreover, premiums and indemnities are to be estimated on the basis of time series data, by farm or homogeneous risk class, which do not simply exist in most developing countries.

Thus one can conclude that the absence of crop insurance market in most developing countries can be explained by analytical arguments. This is a case of market failure due to information externality. But, considering the overriding importance of crop insurance in peasant economies, an alternate solution is called for. In the following section, an attempt is made to develop a model of crop insurance as a decentralised plan and to characterise its properties.

IV.4. A Model of Public Crop Insurance

Consider a peasant economy composed of a large number of identical farmers owning 'A_0' units of land each. A typical farmer's income measured in units of the homogeneous agricultural output is given by:

$$Z = KA^{\alpha}n+r(A_0-A) \tag{26}$$

But, compared to equation (1) of section IV.3, the interpretations of the two components of Z are different here. As was indicated in footnote (5) of this chapter, r can be treated as the secure return from riskless farming. Thus the two sources of income for the farmer are: (a) $KA^{\alpha}n$, where K is a positive scale factor, A is the area under innovative farming which is assumed to be risky, $\alpha < 1$ is the output elasticity of land under risky farming and n is the random variable representing the riskiness of such farming; (b) $r(A_0-A)$, where r is the return from unit area of land under traditional riskless farming and (A_0-A) is the area allotted to such farming.

Notice that innovative farming is assumed to have decreasing returns to scale whereas traditional farming is assumed to have constant returns to scale.[11] The former assumption can be justified on the grounds that innovative farming involves a number of inputs other than land and labor such as fertilizer, technical advice and pesticides, the marginal products of which, in general, are decreasing. Because of the absence of these inputs and due to the fact that the operational holdings of the peasants are small enough to be manageable, the assumption of constant returns to land for traditional farming appears to be reasonable. Regarding the treatment of innovative farming as risky and traditional farming as non-risky, we repeat the argument used in chapter III in connection with rural and urban incomes. That is, we wish to study the decision of the farmer regarding the extent of innovative farming when he perceives that income from such farming is relatively uncertain compared to income from traditional farming.

The farmer chooses the area under innovative farming so as to maximise his expected utility of income subject to his resource constraint. He treats the insurance contract as completely determined by the public crop insurance agency. The insurance agency, in turn, selects the optimal insurance contract so as to maximise the expected social utility of farming subject to its break-even financial constraint. The agency treats the area under innovative farming as optimally determined by the farmer in advance. Thus, it is essentially a two-stage maximisation problem. This approach was formalized by Mirrlees [1971], Atkinson [1973], Varaiya [1976] and others.

IV.4.1. <u>An Individual Farmer's Problem</u>

Here we discuss one formulation of the typical farmer's problem, that is, to choose the optimal area under innovative farming. To gain some insight as to the significance of this choice problem, we analyse several comparative static results, some of which are of interest on their own.

In the absence of insurance, a typical farmer's real income is as given in equation (26). The public insurance agency assures a minimum income M to every farmer.[12] Insurance premium per unit area is q. An individual's indemnity is given by

$$X = M - aZ \tag{27}$$

where $a > 0$. This implies that if the crop is very good the indemnity becomes negative.[13] With insurance, farmer's net income is

$$Y = Z + M - aZ - qA$$

$$= (1-a)\{KA^{\alpha}n + r(A_0 - A)\} + M - qA \tag{28}$$

Farmer treats q, M and a as given by the insurance agency. He chooses A so as to maximise the expected utility of his income. That is,

$$\underset{\{A\}}{\text{Max}}\ E\ [(1-a)\{KA^{\alpha}n + r(A_0 - A)\} + M - qA]$$

First order condition for an interior extremum is given by

$$E[U'(Y)\{(1-a)(K\alpha A^{\alpha-1}n - r) - q\}] = 0 \tag{29}$$

or

$$E[U'(Y)(1-a)\frac{\partial Z}{\partial A}] = q\ E[U'(Y)]$$

That is, utility evaluation of the net benefits of bringing one more unit of area under innovative farming is equated to the cost in utility terms. Equation (29) can also be written as

$$(1-a)K\alpha A^{\alpha-1}E[U'(Y)n] = [(1-a)r + q]E[U'(Y)]$$

Therefore

$$A^* = \left[\frac{[(1-a)r+q]E[U'(Y)]}{(1-a)K\alpha E[U'(Y)n]}\right]^{\frac{1}{\alpha-1}} \tag{30}$$

The second order condition requires that for a maximum

$$D = E[U''(Y)\{(1-a)K\alpha A^{\alpha-1}_{n} - [(1-a)r+q]\}^2$$

$$+ U'(Y)(1-a)K\alpha(\alpha-1)A^{\alpha-2}_{n}] < 0 \tag{31}$$

It is clear that if the farmer is risk-averse the second order condition will always be satisfied, as $\alpha < 1$, by assumption.

Comparative Statics

Here we analyse the impacts on farmer's choice of the area to be brought under innovative farming, due to marginal changes in various parameters of the model and the variables controlled by the public insurance agency.

a. Change in q. Implicit differentiation of (29) and some simplifications yield

$$\frac{\partial A}{\partial q} = \frac{A}{D} E[U''(Y)\{(1-a)K\alpha A^{\alpha-1}_{n} - ((1-a)r+q)\}]$$

$$+ \frac{1}{D} E[U'(Y)] \tag{32}$$

The first term can be identified as income effect and the second as substitution effect. Further, the second term is always negative by (31). If one assumes that farmer's behavior is characterized by non-increasing absolute risk-aversion, then it can be easily shown that

$$E[U''(Y)\{(1-a)K\alpha A^{\alpha-1}_{n} - ((1-a)r+q)\}] \gtreqqless 0.$$

Therefore the first term also is negative and hence

$$\frac{\partial A}{\partial q} < 0$$

That is, a marginal increase in the premium rate will lead to a decrease in the area under innovative farming and hence a decrease in the expected agricultural output.

b. Change in r. Implicit differentiation of (29) with respect to r and some simplifications lead to

$$\frac{\partial A}{\partial r} = -\frac{(1-a)(A_0-A)}{D} E[U''(Y)\{(1-a)K\alpha A^{\alpha-1}_{n} - ((1-a)r+q)\}] + \frac{(1-a)}{D} E[U'(Y)] \quad (34)$$

Here also the substitution effect (second term) is always negative. If the farmer's behavior is characterised by non-increasing absolute risk-aversion, the first term becomes positive in which case the sign of $\frac{\partial A}{\partial r}$ depends on the relative strengths of income and substitution effects. If his behavior is characterised by increasing absolute risk-aversion, the first term also becomes negative and hence $\frac{\partial A}{\partial r} < 0$. Hence we can conclude that in the more likely case of non-increasing absolute risk-aversion, a marginal increase in the return to traditional farming can lead either to an increase or decrease in the area under innovative farming, depending on the relative strengths of the associated income and substitution effects.

c. <u>Change in A_0</u>. Proceeding as before, we get

$$\frac{\partial A}{\partial A_0} = -\frac{(1-a)r}{D} E[U''(Y) \{(1-a)K\alpha A^{\alpha-1} \frac{}{n} - ((1-a)r+q)\}] \quad (35)$$

As can be expected, in this case there is only an income effect. Further, if the farmer's absolute risk-aversion is decreasing, it can be shown that

$$\frac{\partial A}{\partial A_0} > 0.$$

Thus, under the most reasonable assumption regarding risk-behavior, one finds that an increase in the endowment of land will lead to increased area under innovative farming.

d. <u>Change in M</u>

$$\frac{\partial A}{\partial M} = -\frac{1}{D} E[U''(Y) \{(1-a)K\alpha A^{\alpha-1} \frac{}{n} - ((1-a)r+q)\}] \quad (36)$$

As before, it can be easily shown that

$$\frac{\partial A}{\partial M} > 0$$

if the farmer's behavior is characterised by decreasing absolute risk-aversion. That is, a marginal change in the minimum assured income determined by the insurance agency will lead to a change in the area under innovative farming in the same direction.

e. <u>Change in a</u>. Here we analyse the impacts of a marginal change in the insurance coverage ratio on the farmer's behavior. Implicit differentiation of (29) with respect to a and some simplifications yield

$$\frac{\partial A}{\partial a} = \frac{1}{D(1-a)} E[U''(Y)Y\{(1-a)K\alpha A^{\alpha-1}n - ((1-a)r+q)\}]$$

$$- \frac{(M-qA)}{D(1-a)} E[U''(Y)\{(1-a)K\alpha A^{\alpha-1}n - ((1-a)r+q)\}]$$

$$+ \frac{1}{D} E[U'(Y)(K\alpha A^{\alpha-1}n-r)] \qquad (37)$$

The first two terms together constitute the income effect and the last term is the substitution effect. The substitution effect can be shown to be always negative, using equation (29). The first term will be positive if farmer's relative risk-aversion is non-decreasing and the second term will be positive if his absolute risk-aversion is non-increasing. Thus under the most reasonable set of assumptions regarding risk-behavior, the income effect due to a marginal change in the coverage ratio is positive whereas the corresponding substitution effect is negative.

f. Change in α. Implicit differentiation of (29) with respect to α and some simplifications yield

$$\frac{\partial A}{\partial \alpha} = - \frac{\log A}{D} E[U''(Y)Y\{(1-a)K\alpha A^{\alpha-1}n - ((1-a)r+q)\}]$$

$$+ \frac{\log A\{(1-a)r(A_0-A)+(M-qA)\}}{D} E[U''(Y)\{(1-a)K\alpha A^{\alpha-1}n$$

$$-((1-a)r+q)\}] - \frac{(1-a)A^{\alpha-1}(1+\alpha \log A)}{D} E[U'(Y)n]$$

$$(38)$$

As before, the first two terms together represent income effect and the last term represents substitution effect. It can be shown that if relative risk-aversion is non-decreasing, absolute risk-aversion is non-increasing and $A > 1$, then

$$\frac{\partial A}{\partial \alpha} > 0.$$

That is, a marginal change in the output elasticity of land under innovative farming will change the area under innovative farming in the same direction under reasonable assumptions.

g. <u>Change in K</u>. We can get

$$\begin{aligned}\frac{\partial A}{\partial K} = & -\frac{1}{KD} E[U''(Y)Y\{(1-a)K\alpha A^{\alpha-1}n - ((1-a)r+q)\}] \\ & + \frac{(1-a)r(A_0-A)+M-qA}{KD} E[U''(Y)\{(1-a)K\alpha A^{\alpha-1}n \\ & - ((1-a)r+q)] - \frac{(1-a)rA^{\alpha-1}}{D} E[U'(Y)n] \qquad (39)\end{aligned}$$

The first term is negative if relative risk-aversion is increasing and the second term is negative if absolute risk-aversion is decreasing. But the third term, substitution effect is always positive and hence the sign of $\frac{\partial A}{\partial K}$ depends on the relative magnitudes of income and substitution effects.

h. <u>Change in risk</u>.

Following the procedure established in earlier chapters, define

$$n^* = \delta n + \theta$$

where δ and θ are two shift parameters with initial values 1 and 0 respectively. To restore mean,

$$dE(n^*) = dE(\delta n + \theta) = 0$$

which implies

$$\frac{d\theta}{d\delta} = -\bar{n}$$

Farmer's net income can be written as

$$Y = (1-a)\{KA^{\alpha}(\delta n+\theta)+r(A_0-A)\} + M-qA$$

Implicitly differentiating the corresponding first order condition with respect to δ, evaluating the derivatives at the initial values of δ and θ and using $\frac{d\theta}{d\delta} = -\bar{n}$,

$$\begin{aligned}\frac{\partial A}{\partial \delta} = &-\frac{1}{D}E[U''(Y)Y\{(1-a)K\alpha A^{\alpha-1}\bar{n} - ((1-a)r+q\}] \\ &+ \frac{(1-a)r(A_0-A)+(M-qA)+(1-a)A^{\alpha}\bar{n}}{D}E[U''(Y)\{(1-a)\alpha A^{\alpha-1}\bar{n} \\ &-((1-a)r+q)\}] - \frac{(1-a)K\alpha A^{\alpha-1}}{D}E[U'(Y)(n-\bar{n})] \qquad (40)\end{aligned}$$

The first two terms, representing income effect, can be shown to be negative if relative risk-aversion is non-decreasing and absolute risk-aversion is non-increasing. Further, it can also be shown that the third term, substitution effect, is negative for all risk-averse farmers. Therefore, under the most reasonable assumptions regarding farmer's risk-behavior we find that

$$\frac{\partial A}{\partial \delta} < 0$$

implying that a reduction in risk will increase the area under innovative farming and hence the expected output.

i. Change in mean

Here we analyse the impacts of a 'risk-preserving' shift in the distribution of the random variable on the behavior of the farmer. Proceeding as before, define

$$n^* = n+\theta$$

where θ is a shift parameter with 0 as initial value. Farmer's net income becomes

$$Y = (1-a)\{KA^{\alpha}(n+\theta)+r(A_0-A)\} + M-qA$$

Implicitly differentiating the corresponding first order condition with respect to θ and evaluating the derivatives at $\theta = 0$,

$$\frac{\partial A}{\partial \theta} = -\frac{(1-a)A^{\alpha}}{D} E[U''(Y)\{(1-a)K\alpha A^{\alpha-1}n - ((1-a)r+q)\}]$$

$$-\frac{(1-a)K\alpha A^{\alpha-1}}{D} E[U'(Y)] \quad (41)$$

The first term is positive if absolute risk-aversion is non-increasing and the second term is always positive. Hence

$$\frac{\partial A}{\partial \theta} > 0,$$

implying that a rightward shift in the distribution of n without changing the riskiness of farming will increase the area under innovative farming.

The last two results are especially interesting. They imply that the role of risk-reducing public policies is not reduced under a public insurance program. This reinforces our earlier argument that crop insurance should be considered as complementary to the various other agricultural development programs.

IV.4.2. The Planner's Problem

In this section we attempt one of several possible formulations of the insurance agency's problem, namely to choose an optimal insurance program. Our basic assumption in this section is that the insurance agency is risk-neutral[14] and as such, it maximises the expected output of a typical farmer subject to its own break-even financial constraint.

As was discussed earlier, the farmer, while choosing his optimal A, assumes that the insurance contract C(a,q,M) is given to him. That is, he treats a, q and M as given parameters. Hence the optimal A can be expressed as an implicit function of the parameters as

$$A^* = A^*(a,q,M) \tag{42}$$

Several specific functional forms of the utility function of the farmer and the density function of n were tried, but none yielded an explicit solution for A*. Hence, we proceed with the above implicit solution for A* to characterise the solution of the planner's problem.

The planner maximizes

$$E(Z) = E[KA^{*\alpha}n+r(A_0-A)] \tag{43}$$

subject to

$$E[X] = qA^* \tag{44}$$

and

$$M \geq \overline{M} \tag{45}$$

That is, the public insurance agency chooses the insurance contract C(a,q,M) so as to maximize the expected output (income) of the farmer subject to the break-even financial constraint that the expected indemnity equals the premium receipt and the exogeneously determined minimum income is assured to each farmer.

But in view of equation (27), equation (44) states that

$$qA^* + a\overline{Z} = M$$

where $\overline{Z}$ denotes the expected value of Z. And in view of equation (45)

$$qA^* + a\overline{Z} \geq \overline{M} \tag{46}$$

Setting up the Lagrangean,

$$L = KA^{*\alpha}\bar{n}+r(A_0-A^*)+\lambda[qA^*+a\{KA^{*\alpha}\bar{n}+r(A_0-A^*)-\bar{M}] \tag{47}$$

where $\lambda < 0$, the first order conditions for an interior optimum are

$$\frac{\partial L}{\partial a} = K\bar{n}\alpha A^{*\alpha-1}\frac{\partial A^*}{\partial a} - r\frac{\partial A^*}{\partial a} + \lambda[q\frac{\partial A^*}{\partial a} + \{KA^{*\alpha}\bar{n}+r(A_0-A^*)\}$$

$$+ a\{K\bar{n}\alpha A^{*\alpha-1}\frac{\partial A^*}{\partial a} - r\frac{\partial A^*}{\partial a}\}] \tag{48}$$

and

$$\frac{\partial L}{\partial q} = K\bar{n}\alpha A^{*\alpha-1}\frac{\partial A^*}{\partial q} - r\frac{\partial A^*}{\partial q} + \lambda[A^*+q\frac{\partial A^*}{\partial q} + a\{K\bar{n}\alpha A^{*\alpha-1}\frac{\partial A^*}{\partial q}$$

$$- r\frac{\partial A^*}{\partial q}\}] = 0 \tag{49}$$

That is

$$[K\bar{n}\alpha A^{*\alpha-1}-r+\lambda\{q+a(K\bar{n}\alpha A^{*\alpha-1} - r)\}]\frac{\partial A^*}{\partial a}$$

$$= -\lambda[KA^{*\alpha}\bar{n}+r(A_0-A^*)] \tag{48a}$$

and

$$[K\bar{n}\alpha A^{*\alpha-1}-r+\lambda\{q+a(K\bar{n}\alpha A^{*\alpha-1}-r)\}]\frac{\partial A^*}{\partial q} = -\lambda A^* \tag{49a}$$

or

$$B\frac{\partial A^*}{\partial a} = -\lambda[KA^{*\alpha}\bar{n}+r(A_0-A^*)] \tag{48b}$$

and

$$B\frac{\partial A^*}{\partial q} = -\lambda A^* \tag{49b}$$

where

$$B = [K\bar{n}\alpha A^{*\alpha-1} - r + \lambda\{q + a(K\bar{n}\alpha A^{*\alpha-1} - r)\}]$$

$$= (1+\lambda a)(K\bar{n}\alpha A^{*\alpha-1} - r) + \lambda q$$

Using equation (32), it can be easily seen from (49b) that B is negative under reasonable assumptions regarding farmer's risk-behavior. Further, from (48b) and (49b), we get

$$\frac{\partial A^*}{\partial a} = \frac{1}{A^*}\frac{\partial A^*}{\partial q}\ [KA^{*\alpha}\bar{n} + r(A_0 - A^*)] \tag{50}$$

Using equations (32) and (37), equation (50) can be rewritten as

$$\frac{1}{D(1-a)} E[U''(Y)Y\{(1-a)K\alpha a^{*\alpha-1}_{\ n} - [(1-a)r+q]\}]$$

$$- \frac{(M-qA^*)}{D(1-a)} E[U''(Y)\{(1-a)K\alpha A^{*\alpha-1}_{\ n} - [(1-a)r+q]\}]$$

$$+ \frac{1}{D} E[U'(Y)(K\alpha A^{*\alpha-1} - r)]$$

$$= \frac{1}{D}[KA^{*\alpha}\bar{n} + r(A_0 - A^*)]\ E[U''(Y)\{(1-a)K\alpha A^{*\alpha-1}_{\ n}$$

$$- [(1-a)r+q]\}] + \frac{1}{A^*D}\ [KA^{*\alpha}\bar{n} + r(A_0 - A^*)]\ E[U'(Y)]$$

In order to effect further simplifcation, we make a reasonable assumption that the typical farmer's behavior is characterized by constant relative risk-aversion. The above expression can be now written as

$$\frac{1}{D} E[U'(Y)(K\alpha A^{*\alpha-1}_{\ n} - r)] - \frac{1}{A^*D}\ [KA^{*\alpha}\bar{n} + r(A_0 - A^*)]\ E[U'(Y)]$$

$$= \frac{1}{D}\left[\frac{KA^{*\alpha}}{n}+r(A_0-A^*)\right] E\left[U''(Y)\left\{(1-a)\frac{K\alpha A^{*\alpha-1}}{n} - [(1-a)r+q]\right\}\right]$$

$$+ \frac{(M-qA^*)}{D(1-a)} E\left[U''(Y)\left\{(1-a)\frac{K\alpha A^{*\alpha-1}}{n} - [(1-a)r+q]\right\}\right] \quad (51)$$

From equation (29),

$$E\left[U'(Y)\left\{(1-a)\left(\frac{K\alpha A^{*\alpha-1}}{n}-r\right)-q\right\}\right] = 0$$

That is

$$E\left[U'(Y)(1-a)\left(\frac{K\alpha A^{*\alpha-1}}{n}-r\right)\right] = qE[U'(Y)]$$

That is

$$E\left[U'(Y)\left(\frac{K\alpha A^{*\alpha-1}}{n}-r\right)\right] = \frac{q}{1-a} E[U'(Y)] \quad (52)$$

Using equation (52), equation (51) reads,

$$\frac{q}{(1-a)D} E[U'(Y)] - \frac{1}{A^*D}\left[\frac{KA^{*\alpha}}{n}+r(A_0-A^*)\right] E[U'(Y)]$$

$$= \frac{1}{D}\left[\frac{KA^{*\alpha}}{n}+r(A_0-A^*) + \frac{(M-qA^*)}{(1-a)}\right]$$

$$E\left[U''(Y)\left\{(1-a)\frac{K\alpha A^{*\alpha-1}}{n} - [(1-a)r+q]\right\}\right]$$

Cancelling D's on both sides,

$$E[U'(Y)]\left[\frac{q}{(1-a)} - \frac{KA^{*\alpha-1}}{n} - \frac{rA_0}{A^*} + r\right]$$

$$= \left[\frac{KA^{*\alpha}}{n}+r(A_0-A^*) + \frac{(M-qA^*)}{(1-a)}\right]$$

$$E\left[U''(Y)\left\{(1-a)\frac{K\alpha A^{*\alpha-1}}{n} - [(1-a)r+q]\right\}\right] \quad (53)$$

That is

$$-\frac{1}{A^*} E[U'(Y)][KA^{*\alpha}\bar{n}+r(A_0-A^*) - \frac{qA^*}{(1-a)}]$$

$$= E[U''(Y) \{(1-a)K\alpha A^{*\alpha-1}n - [(1-a)r+q]\}]$$

$$[\frac{M}{(1-a)} - \frac{qA^*}{(1-a)} + KA^{*\alpha}\bar{n}+r(A_0-A^*)]$$

That is

$$[KA^{*\alpha}\bar{n}+r(A_0-A^*) - \frac{qA^*}{(1-a)}]$$

$$\{\frac{E[U'(Y)]}{A^*} + E[U''(Y) \{(1-a)K\alpha A^{*\alpha-1}n - [(1-a)r+q]\}]\}$$

$$= \frac{M}{(1-a)} E[U''(Y) \{(1-a)K\alpha A^{*\alpha-1} n - [(1-a)r+q]\}] \tag{54}$$

Known, under constant relative risk-aversion, are

(1) $E[U''(Y)\{(1-a)K\alpha A^{*\alpha-1} n - [(1-a)r+q]\}] > 0$

and

(2) $\frac{1}{A^*} E[U'(Y) + E[U''(Y) \{(1-a)K\alpha A^{*\alpha-1} n - [(1-a)r+q]] > 0$

Therefore

$$KA^{*\alpha}\bar{n}+r(A_0-A^*) > \frac{qA^*}{1-a}$$

That is

$$E[Z] > \frac{qA^*}{1-a}$$

or

$$\frac{\bar{Z}}{A^*} > \frac{q}{1-a}$$

or

$$\frac{A^*q}{1-a} < \bar{Z}$$

Thus, we have the proposition that the planner's optional insurance contract is characterized by the relation that the ratio of insurance premium to one minus the coverage ratio is less than the expected income in the absence of insurance. Notice that this rather simple relation holds good only if the farmer's behavior is characterized by constant relative risk-aversion.

IV.5. Concluding Remarks

As elsewhere in the thesis, in this chapter also we stressed the role of output uncertainty due to natural hazards on peasant's decision-making. Specifically, we discussed certain analytical issues regarding agricultural insurance as a mechanism for improved resource allocation in peasant agriculture.

The chapter started with a discussion of certain conceptual and analytical issues which demonstrated the need for a separate theoretic analysis of crop insurance. Thus, using a rather simple model, we have established that in a situation of imperfect information, a market for crop insurance may not exist at all. Further, we argued that such imperfect information is the rule rather than exception in the case of peasant agriculture.

But, considering the overriding importance of crop insurance in peasant agriculture, an alternative solution is called for. In section 4 of this chapter, such an attempt is made. A public insurance model is developed as a two-stage optimization problem. The farmer chooses the area under innovative farming to maximize his expected utility of income subject to his resource constraint, treating the insurance contract as completely determined by the public crop insurance agency. The insurance agency, in turn, selects the optional insurance contract so as to maximize the expected social utility of farming subject to its break-even financial constraint, treating the area under innovative farming as optimally determined by the farmer, in advance. It may be mentioned that even after making a number of simplifying assumptions, the second part of the problem remains mathematically rather complicated and as such a complete solution is not available.

Notice that the main concern of this chapter has been to give analytical support for the observation that even though there is a clear social need for crop insurance, the market has failed to provide such an insurance. Further, we showed that a public crop insurance has a social use in the sense that it improves the allocation of resources in peasant farming, though it may fall short of providing a pareto optimum solution.

Footnotes

1. Arrow [1971], p. 137.

2. Compared to developed countries the risk of crop failure is much more serious in developing countries. Also, the risk-bearing capacity of farmers in developed countries is much higher.

3. This, indeed, happened in U.S.A. when insurance companies entered crop insurance market during the early years of this century. For further details, see Ray [1967], chapter 7.

4. One can argue that instead of spreading risk over space, insurance companies can spread risk over time. That is, local insurance companies can offer contracts so as to equate the premium collected to the expected indemnity payment over a number of years. But, due to the absence of well-developed capital markets, insurance companies may find this arrangement unattractive.

5. Alternatively r can be considered as return from cultivation of a risk-resistant crop or cultivation of the same crop using traditional technology which is relatively secure. In that case we have to introduce an appropriate production function.

6. The present premium structure would make the payoff per acre relation to premium per acre a decreasing function of the area. This can be rectified by setting the premium proportional to KA^{α}, in which case payoff per acre relation to premium per acre becomes constant. However, it can be easily verified that both formulations lead to identical solution. And the present formulation has the added advantage of practical feasibility.

7. In the real world many of the insurance firms, especially smaller ones, may indeed be risk-averse. But risk-neutrality of insurance firms is a usual assumption in analytical work. See, for example, Rothschild and Stiglitz [1976].

8. A Nash equilibrium can be defined as a set of contracts such that when expected utility maximizing agents choose contracts: i) no contract in the equilibrium set makes negative profits; and ii) there is no contract outside the equilibrium set, if offered, will make a non-negative profit.

8[1]. Rothschild and Stiglitz provides a diagrammatic proof. For a rigorous proof, see Wilson (1976).

9. A formal model involving simultaneous determination of the area and the insurance contract by the farmer was attempted. But it was found that mathematical expressions involved in the solution are extremely complicated and intractable.

10. See Arrow's comments on Radner [1970].

11. A technical limitation associated with this formulation is that because of the Cobb-Douglas technology of innovative farming, one has to assume that all peasant farmers allocate some area of land to such farming.

12. In the present analysis we assume that M is exogeneously determined. It may be that the minimum income is determined on the basis of minimum requirements of the peasant family, considering nutritional and other requirements.

13. The actual implementation of such an insurance program may give rise to many practical problems. One possibility may be to integrate crop insurance with agricultural income taxation.

14. Risk-neutrality of the government appears to be a reasonable assumption by all accounts.

CHAPTER V

THE ROLE OF AGRICULTURAL INSURANCE IN PEASANT ECONOMIES

V.1. Introduction

In chapter IV our main concern was with certain analytical issues regarding agricultural insurance. After providing certain theoretical justifications for the non-existence of such insurance in peasant economies, we developed a theoretical model of public crop insurance. In the present chapter our main emphasis is on the institutional aspects and the feasibility of such insurance. Considering the many simplifying assumptions underlying the theoretical model and the incompleteness of the mathematical solution, no attempt is made to integrate the discussion in the present chapter with that in chapter IV.

As was illustrated in the introductory chapter, the principal characteristic which distinguishes agriculture from other productive sectors is its great dependence on nature. Uncertainty of crop output due to natural hazards is one of the basic risks which every farmer has to face. But majority of farmers in most countries, due to in-costs of such risk-bearing may well exceed the social benefits from such risk-bearing. Considering risks in the aggregate, insurance is best suited to situations where the probability of loss is very small while the amount at risk is large. But in many such cases the cost of information needed to formulate a coherent probability distribution may be too high. In such cases insurance companies offer protection only at a very high price which makes it unattractive to the individual. The classification of gambling as evil has a pragmatic basis that is also related to the high cost of information.

Another important problem facing all types of risk-shifting in general and insurance in particular is 'moral hazard'. The usual insurance literature defines moral hazard as the intangible loss-producing propensities of the insured. It implies that the insurance policy might itself change the incentives and therefore the probabilities upon which the insurance company relied. While commenting on Radner [1970], Arrow argues that moral hazard can be considered as a special case of lack of information. For example, if an insurance company could distinguish whether a fire was due to arson or not, it could pay in the latter case but not in the former. Thus moral hazard arises only because the insurance company cannot distinguish between two states of nature. If the company can monitor the individual's action taken in advance of nature's act, the adverse incentives problem can be avoid-that the losses wholly or partly are shared by the farmers themselves. A contractual right to assistance in the event of crop failure, further enables the farmers to improve their credit-worthiness and stabilizes their incomes which in turn stabilizes the rural economy in particular and the entire economy in general. Also it gives the farmers greater confidence to venture into the adoption of new and improved farming practices and in making greater investments in agriculture. Crop insurance is thus an important link in the chain of diverse measures to secure stabilization, growth and fair distribution in the agricultural industry. It is complementary, on the one hand, to activities designed to strengthen the base of agriculture, namely, irrigation, drainage, land reclamation and other means of increasing agricultural output and on the other hand, to price and other income support measures. The importance of crop insurance is forcefully stated in one of the early reports[3] of U.S. Crop Insurance Corporation as follows:

> "Large sums of money are spent every year in agricultural research to develop better varieties of seed, more efficient means of controlling insects and diseases and improved methods of farming. Soil conservation practices have been encouraged by making available technical assistance as well as cash payments to the farmer. Price supports have been provided for more than a decade to help maintain some degree of stability in farm income. Despite all these measures the farmer will receive but little income in any year if he invests his time, money and effort to produce a crop only to be faced with a crop failure due to some cause over which he has no control. Insurance protec-

tion spans this crop failure gap."

This statement is even more true in most developing countries today where vast efforts are made to improve farm productivity and income through substantial investments, price policies and spread of modern inputs and techniques. After a decade of great enthusiasm about 'Green Revolution' the general observation is that it has suceeded only in areas of substantially reduced risk and that too only among better-off farmers,[4] As we have discussed elsewhere, modern methods of cultivation involve increased risk compared to traditional methods. Also the cost of cultivation is much higher in the case of high yielding varieties of seeds. Even when credit facilities are available, small farmers are reluctant to make use of them out of fear that crop failures in bad weather years will involve them in such heavy losses that they may have to sell their land in order to repay debts. Branding small farmers as 'conservative' or 'irrational' is begging for non-economic explanation for an essentially economic phenomenon. As Clifton Wharton warned[5]: Attempts at change, especially those which come in direct conflict with the fundamental goals of security and survival, must take into account the degree of risk and uncertainty associated with the change.

With these introductory remarks, the rest of this chapter proceeds as follows. In section two the role of risk-bearing and the institutional framework for risk-shifting in modern economies along with the problems of risk-shifting, in general, are discussed briefly. Section three deals with the traditional devices of risk-bearing in peasant economies and their limitations in some detail. Section four is devoted to a detailed discussion of special features of agricultural insurance. In section five, a viable model of crop insurance, specifically in the context of India, is developed. Final section gives a few concluding comments.

V.2. Risk-bearing in Modern Economies

Risk-aversion is a universal behavioral mode, though people do gamble occasionally. A person may buy insurance and at the same time enter into gambles. This can be explained either by characterising his preferences over different levels of wealth differently as Friedman and Savage [1948] did or by explicitly treating gambles as arguments in his utility function along with wealth. Also it may be possible that gambler's subjective evaluation of risk may be much more favorable to him than it in fact is. In any case, much more people insure their lives and property than those who go to Las Vegas.

Under the postulate of risk-aversion, an individual will seek to avoid risk if the cost of doing so is less than the gain from the risk averted. He may avert risk by 1) searching for information about the future (which may not be attainable even at infinitely high cost, 2) by choosing less risky options when investing (which include portfolio diversification), or 3) by choosing among arrangements with which his burden of risk can be dispersed to other individuals - such as insurance and various contractual arrangements. The choice of these arrangements is made so as to maximise the gain from risk-dispersion subject to the constraint of transaction costs. Insurance is applicable only when the risks can be reduced to a statistical basis; otherwise it is the function of speculators to assume the risk.

Shifting of risks, the very essence of insurance, occurs in many forms in modern economies. In a capitalist system, the owner of a business typically is supposed to assume all the risks of uncertainty associated with his activity. But society has long recognised the need for permitting him to shed some of the risks. An individual's capacity for running a business well need not be accompanied by his desire or ability for bearing the accompanying risks, and a series of institutions for shifting risks has evolved. The most important of these are stock market and insurance. Generally some of the socially most profitable undertakings are the riskiest ones. Innovative technology, natural resource exploration and most of the research projects are examples. But for these institutions, many of the socially profitable undertakings might not have taken place.

As Arrow [1971, pp. 138] has argued, an ideal situation is one where one could find a market in which one can insure freely against any economically relevant event. That is, an individual should be able to bet, at fixed odds, any amount he wishes on the occurrence of any event which will affect his welfare in one way or other. The premium on the insurance should be determined, as any other price, so that supply and demand are equal. Under such a system, productive activity and risk-bearing can be divorced, each being carried out by the one or ones best qualified.

But the scope of existing risk-bearing institutions is very much limited compared to the ideal situation suggested above. This incomplete risk-shifting arises mainly because of a number of factors which can be classified under the general heading of 'market failure' due to 'incomplete information'. Below, we briefly discuss these factors and the ways by which they limit the role of insurance.

In the first place, many risks are classified as 'uninsurable'. But there is no standard criterion to determine whether a particular risk is insurable or not. The risks that are insurable vary somewhat from company to company, and there are special groups, such as Lloyd's which will, for suitable prices, insure many risks that ordinary insurance companies will not. Also there are many risks which should not be insured as the social costs of such risk-bearing may well exceed the social benefits from such risk-bearing. Considering risks in the aggregate, insurance is best suited to situations where the probability of loss is very small while the amount at risk is large. But in many such cases the cost of information needed to formulate a coherent probability distribution may be too high. In such cases insurance companies offer protection only at a very high price which makes it unattractive to the individual. The classification of gambling as evil has a pragmatic basis that is also related to the high cost of information.

Another important problem facing all types of risk-shifting in general and insurance in particular is 'moral hazard'. The usual insurance literature defines moral hazard as the intangible loss-producing propensities of the insured. It implies that the insurance policy might itself change the incentives and therefore the probabilities upon which the insurance company relied. While commenting on Radner [1970], Arrow argues that moral hazard can be considered as a special case of lack of information. For example, if an insurance company could distinguish whether a fire was due to arson or not, it could pay in the latter case but not in the former. Thus moral hazard arises only because the insurance company cannot distinguish between two states of nature. If the company can monitor the individual's action taken in advance of nature's act, the adverse incentives problem can be avoided by structuring the insurance payoff function to enforce the choice of the appropriate decision by the individual. It is easy to see why insurance against failure of business or of research projects has not arisen; the incentive to succeed may be too greatly reduced. A common solution to moral hazard in insurance practice is coinsurance by which part of the risk is borne by the insured himself. Thus automobile insurance usually involve a deductible, unemployment insurance payments begin only after a few weeks of unemployment, house and property cannot be insured for more than their actual values and in health insurance the patient bears part of the cost, usually the prescription charges. In agricultural insurance the maximum indemnity is usually fixed as the actual cost incurred by the farmer.

Whenever insurance is voluntary there is the problem of 'adverse selection'. This is purely a problem of lack of information. In most cases the individuals involved may belong to different risk classes. Usually the individuals themselves have their subjective or objective evaluation as to which class they belong. But insurance agencies may not have similar information and the cost of collection of such information may be very high. Individuals, in general, think that it is not in their interest to divulge such information. So the insurance agencies cannot distinguish between high and low risk customers and as such have to provide uniform insurance which will be relatively more attractive to high-risk individuals. That is, only high-risk individuals will buy insurance and hence insurance companies will incur heavy losses. This, in fact, happened in U.S.A., when insurance companies entered crop insurance market during the early years of this century.[6] In a recent paper, Rothschild and Stiglitz [1976] demonstrated in a simple competitive model that if the insurance agencies cannot distinguish between high and low risk customers, then a market equilibrium may not exist. Further, they made an interesting observation that the presence of the high-risk individuals exerts a negative externality on the low-risk individuals, and that high-risk individuals are no better off than they would be in isolation. In actual insurance practice there are various checks to curb the problem of adverse selection. Thus, in life insurance, usually a medical report is mandatory and in automobile insurance, the driving history of the individual is verified.

Also, as Spence and Zeckhauser [1971, pp. 380] noted, there should be substantial independence in the incidence of the random event for the existence of insurance contracts. If this condition is not satisfied the working of the law of large numbers on which premium and indemnity are based breaks down. In a subsequent section we argue that this is one of the main reasons for non-existence of crop insurance market, especially in developing countries.

For reasons we have discussed so far and others, the scope of insurance market is very much limited in modern economies. This failure of market to achieve adequate risk-shifting lead to compensatory alterations in social institutions. Licensing, bankruptcy and limited liability, direct controls and large business organizations are examples of such compensatory alterations. But all of these are steps away from the free working of the price system.

V.3. Traditional Solutions to Agricultural Risk

Here we briefly discuss how peasant societies meet the risk of farming. Broadly there are four ways of meeting any risk: a) avoidance, b) prevention, c) bearing, and d) transfer. In earlier days, when land was abundant, farmers had the option of choosing the location of their farms so as to minimize the risk of natural hazards. But in most developing countries this choice is no more available because of the very high man-land ratio. Also, as a general behavior mode risk-avoidance is not always commendable.

In general, the most important way of meeting a risk is to prevent it. But even with all the scientific and technological achievements, man is still helpless when confronted with the furies of nature. Science and technology have very little control over cyclones, earthquakes and droughts. But modern knowledge and large investments together are capable of preventing or, at least reducing the impact of many other natural calamities. Thus water management through dams and canals and various pest and disease control measures, for example, substantially reduce the uncertainty of farming. However, due to resource scarcity and economies of scale most of these facilities are not available to poor farmers in developing countries. But, peasant societies, through thousands of years of experimentation, have perfected their own risk-prevention measures. These include many traditional methods of irrigation and drainage, crop rotation, replanting, selection of seeds, land preparation and even predicting the impending climatic changes based on past experience. Hopper [1965] gives a vivid description of the many ways in which farmers in a typical Indian village practice various risk-prevention measures.

But there are cases where there is trade-off between the cost of preventing risks and the cost of bearing them. Also, some risks are not preventable at any cost. In such cases the risk should be either borne by the farmer himself or should be transferred to another individual or agency or society at large.

First we consider the case of risk-bearing or self-insurance. A rich farmer could accumulate funds or grain in good years to support him in bad years; that is, he may spread risk over time. Also, he may diversify his farming over different plots of land with different levels of risk or over different crops or methods involving different levels of risk; that is, he may spread risk over space. But for a small farmer both these options may not be available. For him there is concentration of risk in time and space. He tries to minimize risk by practicing the least risky method of farming even when there is an option involving a much higher output with a higher risk. This phenomenon is termed 'Survival Algorithm' by Lipton [1968, pp. 332-38]. For most poor farmers local varieties of seeds combined with traditional techniques is the rational choice. This is the basic reason for the failure of green revolution among small farmers. One has to make a distinction between desire and ability for risk-taking. While the former depends on the innate propensity of the individual, the latter mainly depends on the wealth position of the individual. There is general agreement among agricultural field experts that what the small farmers lack is only the latter quality. Another manifestation of risk-minimizing behavior of small farmers is division of a single holding into several tiny plots.[7] With this, he achieves some amount of risk-spreading over space; but only at a cost in terms of production efficiency and loss of land.

A good many of the traditional institutions and practices are essentially insurance-surrogates. Thus in a joint-family system,[8] several nuclear families live together and cultivate a joint farm. This is essentially a mutual-insurance arrangement in which each unit exchanges one risk for another - for a small chance of a large loss, a large chance of a small loss. Many farmer borrowers prefer to pay interest in grain rather than in cash, though the standard grain-rate is almost double the cash rate. Higher interest rate buys the borrower an insurance against low crop-prices. But the most important and perhaps the most controversial risk-sharing arrangement in peasant economies is share-cropping which is essentially an insurance against low crop outputs. But the traditional view[9] of this practice was essentially that of an excise tax and as such was considered inefficient as an allocative mechanism. Recently, interest in this issue was revived and a number of authors[10] analysed the question of efficiency of share-cropping relative to fixed-rent contracts. Though there is no consensus regarding the appropriate institutional framework and the nature of farm lease market, a general conclusion is that share-cropping is efficient if the role of agricultural risk is taken into account. But as Rao [1971, pp. 583-92] argued and empirically demonstrated using Indian farm data, share-cropping, as an insurance mechanism, may not be conducive to innovative farming. Also, in countries with land shortage, the bargaining position of the share-cropper is rather weak and this leads to very high implicit premium loadings.

Perhaps risk-shifting in its perfect form manifests in peasant economies as one of the worst social institutions, namely, bonded labor. According to this a laborer enters into a contract with a landlord to work on his farm on a permanent basis in return for a guaranteed subsistance income for himself and his family. One could find many more examples of partial and complete risk-transfer mechanisms in traditional economies. Most of these insurance surrogates have two common features: the implicit insurance premiums are heavily loaded against the individuals and even if they are efficient in the static context, they may be highly inefficient in a dynamic sense.[11]

V.4. Special Characteristics of Agricultural Insurance

One can classify agricultural insurance into different types according to different criteria. Classified on the basis of the hazard or hazards insured against, it may be specific risk, combined risk or all risk insurance.

Under specific risk insurance, crops are protected against only or primarily a single specified hazard such as fire, hail, windstorm, flood or drought. The most outstanding development in this group is the insurance of growing crops against the risk of hail damages, which is practiced extensively in most countries of Europe and North America. In the case of combined risk insurance, protection is provided against two or more hazards and they are also fairly common in developed countries. All-risk crop insurance, compared to the other two is a fairly recent development, having attained some importance after U.S.A. and Japan started such insurance in late 1930s.

By far the greatest part of existing crop insurance is on single crops which are usually the major crops grown in an area. However, frequently a farmer's investments, instead of being concentrated in one or two major crops, are distributed among a number of minor crops. The program of multiple or combined crop insurance is devised to offer protection to such farmers. Under this program, crops are not insured separately but are grouped together as a unit and indemnities are payable only when the combined yield falls below the predicted level. But the experience of U.S. federal crop insurance corporation is that farmers prefer single crop insurance.[12]

Based on institutional setup, one can classify crop-insurance into a) private, b) mutual/cooperative, and c) public. The typical private insurance agency is a joint-stock company. Like any other private enterprise, it is a union of capital invested primarily with a view to earning profit.

Mutual insurance is essentially an arrangement by which a group of individuals share each others misfortunes. In a typical mutual there is complete identity of interest between the organization and the individual. Unlike the usual insurance, here the premium is variable

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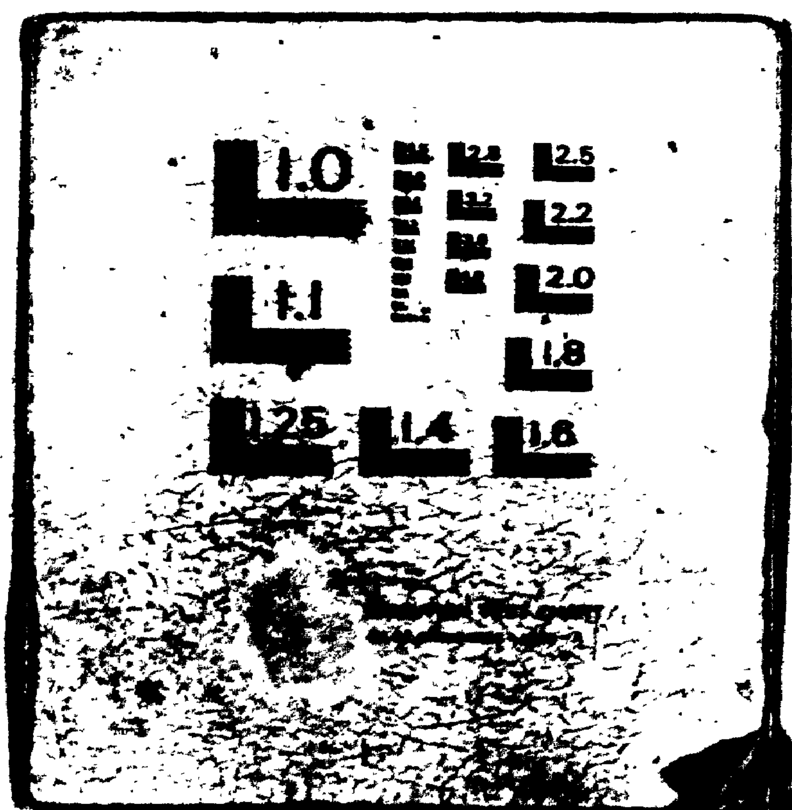

as each person is choosing a large risk of a small loss to a small risk of a large loss. Though the concerned institutional literature makes a distinction between mutuals and co-operatives, for our purpose we can consider a co-operative as a large mutual.

The special characteristics of mutuals and co-operatives as distinguished from those of joint-stock companies, give them certain advantages over the latter as carriers of agricultural insurance. First, they are particularly adapted to handle those risks where moral hazard appears to be strong and, therefore, insurance is required to be carried out under a rigorous reciprocal control on the part of the insured themselves. Second, they are more useful when the risks to be insured are small and widely scattered within a locality, requiring, in the case of big companies, heavy overhead and inspection charges and consequently higher premium rates. Since individual agricultural risks, especially for small farmers, are generally of smaller value than most risks usually insured, and are widely scattered and isolated, they can be insured with relatively greater ease and less expenses locally by mutuals or co-operatives. In fact, agricultural insurance has developed most in those countries where either the farmers themselves have taken initiative in forming mutuals and co-operatives or the state has encouraged them to do so. Examples are many European countries and Japan.

Another factor which especially acts in favor of local mutuals or co-operatives is their almost negligible cost of management. A limited area combined with a large element of voluntary services helps to keep down their management cost to the minimum. A private insurance company, on the average, has to set aside forty to fifty percent of its premium income for the administration of the program.[13] and as such its premium may be almost double that of an efficient mutual. Also, mutuals have the advantage of minimizing adverse selection as all members may know each other and even each other's risk-history of farming.

The main disadvantage of mutuals is that they may not be able to cope with situations of widespread damages. But these types of damages are very common in agriculture. Subsequently we will take up this matter for detailed examination.

Although private companies and co-operatives have been playing important roles in agricultural risk-shifting, generally their scope is limited. There are large classes of farming risks which neither of them would venture to undertake at all, or to the extent that is socially necessary. Here arises the possible need for the third type of organization - the public or governmental insurance.

Public insurance can take a number of forms. They can be public institutions freely competing with private companies. Alberta Hail Insurance Board in Canada is an example of this. A public insurance institution working in competition with private insurance companies is useful in at least two respects. First, as it does not have to earn high profit for paying dividends to share holders, it can reduce costs and therefore offer lower premiums, which helps to lower the rates of private companies also. Second, it is forced to keep down its own costs as it has to seek business in competition with others; this keeps it free from the abuses of monopoly.[14]

The second type of public insurance institutions are those which have a legal or virtual monopoly of insurance although the insurance itself is voluntary. Examples are U.S. Crop Insurance Corporation and Coffee Insurance in Puerto Rico. This form of insurance is particularly suited in cases where the social benefits of risk-bearing are important but at the same time governments are not willing to compel people to buy insurance. Here a main problem may be adverse selection.

Public insurance institutions of a third type comprise those where insurance is compulsory. In most centrally planned economies some form of compulsory crop insurance operates. Thus in the U.S.S.R., state Insurance Administration has the monopoly of all insurance including compulsory crop insurance for collective farms. In Yugoslavia, insurance against hail and fire is compulsory for all major crops grown in the 'social sector', that is, by state and co-operative farms. Other countries with compulsory insurance include Sri Lanka, where paddy crop insurance is compulsory and Jamaica, where banana crop insurance is compulsory. Compulsory crop insurance of this type usually covers costs of production only and not the full value of the yield.

A fourth category of public insurance is the 'optional application of compulsory insurance', that is, where compulsory insurance will be introduced only when majority of individuals in a locality opted for it. In the province of Saskatchewan in Canada, compulsory hail insurance is organized this way. So is the present crop insurance system in Japan. Another variant of this form is the system of all-risk crop insurance in Mexico which makes it obligatory only for those farmers who apply for agricultural loans from government credit institutions.

Public insurance organizations have greater advantage than private companies usually under the following conditions. First, there are certain risks, which, either because of their greater uncertainties or of larger responsibilities involved, are normally avoided by the private insurance companies. A typical example of this class is the all-risk crop insurance. Again, there are risks which are insured by private companies but not to the extent of the requirements dictated by public interest. Crop-hail insurance, for example, is not sufficiently taken up by farmers in many countries often because of the high premium rates charged by private insurers due to various information costs. Second, public insurance agencies are more suitable than private companies when the risk is more or less of universal character and the insurance is intended to apply to a major part of it as, for example, insurance against sickness, old age, unemployment and accidents in the course of employment. Public bodies would be able to manage such insurance with greater security and less cost to the insured, than private institutions, for, these bodies have no need to earn large profits, have the usual economies of scale and also to some extent the support of public resources.

Third, and perhaps the most important factor favoring public insurance is the consideration of public policy. Insurance is being increasingly looked upon not merely as a commodity to be bought and sold in the market, but as an institution of security which, more or less, must be enjoyed by all. With the development of the concept of Welfare State concerned with the material well-being of all its citizens, insurance against the basic uncertainties of life has become essential. Such responsibility can best be discharged by state through universal and often compulsory insurance.

A scheme of compulsory insurance dictated by public policy differs from voluntary insurance, private or public, in two material respects. First, the adjustment of premiums to risks, which is essential for voluntary insurance to attract low-risk individuals is not strictly necessary in this case. Second, under voluntary insurance, especially when it is private, building up of a huge reserve may be needed, but under compulsory insurance the state need not accumulate any reserve as it has the power of compelling successive generations of citizens to be insured, which helps to maintain a steady flow of premium payments. Moreover, it has the power of taxation to supplement its funds.

Compulsory public insurance has the following principal advantages. First, it assures, at least to the extent of compulsory insurance, a measure of security. But usually there may be provision for additional insurance coverage on a voluntary basis by public or private agencies. The philosophy behind such compulsory insurance was stated by Lord Beveridge as[15]: The state in organizing security should not stifle incentive, opportunity, responsibility; in establishing a national minimum, it should leave room and encouragement for voluntary action by each individual to provide more than that minimum for himself and his family. Secondly, it is relatively easier to administer. The business being assured, it is possible to build up a stable schedule of rates. Thirdly, owing to the compulsion exercised by government, the selling cost is minimized. The cost of collection of premium can be minimized by having them collected by the existing revenue agencies.

The main disadvantages of compulsory insurance are, first, it interferes with free choice, second, being free from competition the insurance agency may adopt schematic bias of judging risks, which leads to inadequate classification and little differentiation in premium rates. This is likely to cause injustice to persons having lighter risks. Third, where compulsory insurance requires the state to share a part of the costs which ultimately comes from the general tax payer, it means that certain people are benefited at the expense of the rest of the society.

Public insurance worked on voluntary principle is free from these difficulties, but it may have the problem of getting sufficient business spread over different risk classes as well as by space and time, which are essential for the success of any insurance scheme. The history of U.S. Crop Insurance Corporation is a typical example for such problems.

V.5. A Viable Public Crop Insurance Program for India

Though in most developing countries private insurance agencies provide insurance protection to most urban risks, there is hardly any developing country where agricultural insurance is taken up by the private sector. Apart from the standard problems of any insurance, like lack of data base, moral hazard and adverse selection, indeed, the most important reason for absence of crop insurance market may be the very special nature of agricultural risk. Unlike other risks like fire and accidents, the incidence of agricultural risks may not be independent among individuals. Thus crop losses, due to floods or droughts, when they occur may be fairly widespread. A private agency with a limited agro-climatic area coverage may be reduced to bankruptcy by such a loss. Indeed, this is the argument we have used in chapter IV to analytically show that crop insurance market may not exist at all.

Many developing countries faced with an urgent task of raising the very low level of agricultural production and unsteady nature of farm income, have been, in recent years giving serious consideration to the usefulness and practicality of agricultural insurance as a public policy. But except very few of them,[16] the vast majority have not taken any concrete steps in this direction. For example, crop insurance in one form or other was under active consideration by the government of India for the last three decades. An expert committee[17] recommended against a model scheme of public crop insurance prepared by the Department of Agriculture of the Government of India mainly on the grounds that the cost in terms of resources and personnel required by that scheme is too high and that alternatively, these resources can be employed to enhance agricultural productivity and reduce crop risk. But in a recent article, Dandekar [1976] has put forward a strong case for crop insurance in India. He contends that the committee based its conclusions on wrong premises and proves his point using crop yield data from the Indian State of Maharashtra. Further, he developed his own model of crop insurance which is comparatively easy to administer and at the same time needs much less resources. In the following pages we outline a viable scheme of crop insurance for India which is essentially a modification over Dandekar's scheme.

We argue, as we have done in the introductory section of this chapter, that public insurance should be looked upon as complementary to other developmental efforts. By removing the basic insecurity of farming, especially from small farmers, the productivity of other investments will be enhanced by the introduction of a public insurance. Any substantial reduction of agricultural risks, in large tracts of India due to droughts and floods, will require astronomically large amounts of resources. Even if, somehow, resources can be made available, it will take a long time for their physical execution. Further, the social cost of such risk reduction may be much higher than the corresponding social cost of risk-bearing. A detailed discussion of the social benefits and costs of risk-bearing in peasant agriculture is found in Weaks [1970, pp. 32-34]. Thus at least as a short and medium term public policy, crop insurance is relevant.

The salient features of the proposed public crop insurance program are as follows:

1. Insurance protection should be limited to crop output and not crop prices. That is, the premiums and indemnities are to be estimated in real terms. Premium collection and indemnity payment can be done in money terms by employing average prices estimated over a number of years. Left to the market forces, any significant output changes may lead to compensatory price adjustments to substantially stabilize the agricultural income. This need not be necessarily true in a country like India where regional variations in the incidence of risk are considerable and at the same time there exists a national market. But more importantly, agricultural price management has been an effective policy of the government for some time. Moreover, large segment of the farmers produce for home consumption only. Also, the benefit of higher prices is no consolation for a farmer who loses his entire crop.

2. The insurance should be all-risk type for adequate protection of the farmer. Since the main purpose of the insurance is to protect the farmer from misfortunes beyond his control, at least all major natural hazards should be protected against. Moreover, there are large tracts in India which are subjected to droughts and floods in almost alternate years.

3. It should be a combined insurance covering all major crops. Unlike the model scheme considered by the expert committee which involved single crop insurance, our scheme will be administratively much simpler. From the point of

view of the farmer also, a crop insurance scheme covering all his crops would be much more meaningful than the coverage of several crops singly. Moreover, in each area, two or three principal crops will give sufficient protection to each farmer. For the purpose of such combined crop coverage, a production index with appropriate weights should be constructed. In general, the variability of the overall productivity of crops is much smaller than the yield variability of individual crops and as such the frequency of indemnification under combined crop insurance will be much less.

4. The insurance should have wide area coverage even as an experimental program. As discussed earlier, one of the main reasons for the absence of crop insurance market is the special nature of agricultural risk, namely widespread crop losses over homogeneous agroclimatic areas, i.e. - the non-independence of risks. In such cases horizontal spread of risk can be achieved only by spatial spread over wide geographical areas. In India this can be achieved in a reasonable sense by national coverage.

5. Insurance should be based on an area approach instead of the usual individual approach. This may be perhaps the most significant departure of the proposed crop insurance program compared to other insurance programs. In usual insurance practice premium and indemnity are assessed on an individual basis. Even though individual approach is the ideal approach and is the one followed by U.S. Agri-

cultural Insurance Corporation, this is, for all practical purpose, impossible for India with its fifty million farmers. An administrative machinery at least as large as the existing developmental framework will be needed for such an insurance program. Moreover, since indemnity is to be determined on an individual basis, the problem of moral hazard may be very serious. For a successful program, continuous monitoring of farmer's behavior from land preparation to harvesting may be needed. The basic idea of an area approach to crop insurance is that the premium and indemnity for a number of farmers over an area will be determined jointly. Every farmer in such an area will pay premium at the same rate and receive indemnity if the average yield in that area falls substantially below the area's normal yield.

6. The success of crop insurance based on area approach depends on the selection of homogeneous areas. The relevant homogeneity is with respect to crop risk and not crop yield. The coefficient of variation of crop yield can be considered as a good measure of risk.[18] Once farmers are classified into homogeneous areas based on the coefficient of variation of crop yield the individual behavior is no more relevant and as such the moral hazard problem is completely eliminated. If premiums for different areas are determined proportional to the coefficient of variation in yield such that over a number of years the total premium received is equal to the total indemnity paid, such an

insurance scheme can be considered truly actuarilly fair among the different homogeneous areas.

7. Is such a scheme a true crop insurance for the farmers? This depends on how far homogeneous each area is with respect to risk. If each farmer's yield and the area average yield move together above or below the respective normal yields, our method is foolproof. If not, many farmers will receive indemnity when their crops are good and many farmers will not receive indemnity when their crops are very bad. Even if one can tolerate the former, it is hard to justify the latter. This problem has to be tackled separately and we will come back to it later. One can also argue that the important concern should be that each area is sufficiently taken care of when the output and income in that area is depressed. Thus in a generally favorable year, even if one or two farmers did suffer, if the output and income in that area are high, then that is a tolerable situation.

8. The existing agricultural statistics system can be used as data-base for the proposed insurance program. India has a fairly satisfactory agricultural statistics system based on sound statistical principles. For example, the crop yield estimates are based on stratified multistage random crop cutting experiments. Detailed data from these crop cutting experiments are available for more than two decades. These can be used to estimate the coefficients of variation and to classify areas based on risk. Also,

to start with, the normal area average yield can be estimated as the past ten year average, though for subsequent years the normal yield should be a moving average for the latest ten years.

9. Determination of Premium and Indemnity. The premium for each area should depend on the riskiness and the terms and conditions of indemnity. As empirically demonstrated by Dandekar,[19] full protection of normal yield will require indemnification in every alternate year and in this case premiums will be prohibitively high. A reasonable scheme may be to protect the farmers for two-thirds of the difference between three-fourth of the normal yield and the actual area average. As was estimated by Dandekar [Ibid, p. 76], such a scheme will involve premiums ranging from approximately two to ten per cent of the yield and indemnification on the average once in four years. To be acturially fair the total premium collected over a number of years, say ten, and over the entire country should be equal to the total expected indemnity payment over the same time and space. We assume that the cost of administration will be borne publicly. As against the estimated cost of administration of government of India's original scheme of 40% of the premium income, a rough estimate of the cost of administration of the present scheme is of the order of 10 to 15 percent of the total premium income.

10. Should insurance be compulsory or optional? Though in principle the area approach charted above is free from

the problem of adverse selection, some amount of compulsion supplemented by propaganda may be needed. The merit of a voluntary scheme is that collection of premium becomes easier as only those farmers who find the scheme attractive would join it. But in that case insurance has to be sold and this is said to account for a good proportion of the cost of administration of the scheme in the U.S.A. Further, if the experience of the co-operative movement in India is any guide, there is also the danger that crop insurance on a voluntary basis will serve mainly the interests of wealthy farmers. A solution to this problem may be optional application of compulsory insurance, as is done in Japan. In our case this may be based on the majority decision of a Panchayat[20] or rural co-operative society. Also the involvement of such a local organization may have the added advantage of an element of mutuality. Moreover, one of the main limitations of the proposed area approach, namely non-payment of indemnity to farmers subjected to individual losses, can be satisfactorily handled by such an organization.

11. Organizational structure of the proposed crop insurance program. The General Insurance Corporation of India, a public sector undertaking, may be best suited to manage the crop insurance program. First, it has already the necessary expertise at all levels needed. Of course, it will require additional staffing and training of personnel. Second, it has offices and field staff spread all over

the country. What is essentially required may be proper coordination between this organization at various levels and the organization of agricultural statistics at various levels. At the local level, the insurance corporation can enlist the cooperation of co-operative banks and rural credit societies.

12. Linking of crop insurance with rural-credit institutions. As Dandekar[21] put it: Without protection from the insecurity of agriculture, the entire structure of agricultural credit in India is in danger of total collapse burying under it the cultivator in perpetual indebtedness. Even the Credit Guarantee Corporation of the Reserve Bank of India protects only the credit institutions against default risk not the farmers. In this context, a modified form of crop-loan insurance program as practiced in Mexico may be worth considering. Crop-loan from public institutions and co-operatives should be compulsorily insured. The premium should be collected in advance from the loan and the indemnity should be adjusted in repayment. This may substantially reduce the inhibition of poor farmers from seeking agricultural loans.

V.6. Concluding Remarks

In this chapter, as elsewhere in this thesis, we stressed the importance of output uncertainty due to natural hazards in peasant agriculture. We argued that, as in modern economies, in peasant agriculture also, the need for risk-shifting is universal. Even in modern economies the scope of insurance market is limited by a number of factors which can be classified under the general heading of 'information externality'. But in the case of agriculture, especially peasant agriculture, over and above information problems, there is the important problem of interdependent risk. Because of these factors there exists virtually no crop insurance market in peasant economies.

But in peasant agriculture, apart from various risk-reduction methods and risk-assumption methods, there are many traditional institutions and practices for risk-shifting. However, most of these insurance surrogates have two common problems: the implicit insurance premiums are heavily loaded against the individuals and even if they are efficient in a static context, they may be highly inefficient in a dynamic sense.[22]

It is in this context that we consider the role of crop insurance as a public policy. Economic growth without distributive justice is no more acceptable to the people and the politicians and policy makers in most developing countries. In most of these countries, fifty to seventy percent of the people directly depend on agriculture for their living. Improvement and stabilization of their incomes are too important to be neglected. Crop insurance as a public policy may definitely involve some subsidization. But in any case, various agricultural subsidies of indirect nature such as reduced interest rates and direct subsidies during the time of crop failure exist in various countries. Based on the simple principle of the superiority of direct subsidy to indirect subsidy one can argue that an insurance premium subsidy is superior to an interest rate subsidy. Moreover, as we have discussed elsewhere, income tax on farmers, in general, will not adversely affect productive efficiency and as such sizeable amounts can be collected as taxes, especially from well-off farmers who are the beneficieries of most of the past developmental programs and the same can be used for subsidization of public crop insurance.

Finally, we have developed a simple, but viable model of crop insurance, specifically in the context of India. Though this is not the ideal crop insurance, considering the practical limitations, this second best policy may be worth application. Further, one can explore the possibility of linking such a crop insurance program with the existing statutory distribution of food grains through public agencies and the buffer stock of food grain in India. Also, one can imagine the possibility of linking country crop insurance programs with the World Food Program of the FAO.

Footnotes

1. One can argue that a decline in farm output may be offset by a compensatory price change. But this need not be necessarily true in a country like India where regional variations in the incidence of agricultural risk is considerable and at the same time there exists a national market. Moreover, large segment of the farmers produce for home consumption only. Also, there is no benefit from compensatory price changes for a farmer who loses the entire crop.

2. For details of such measures in U.S.A., see Ray [1967, chapter 4] and in India see Dandekar [1976, pp. 75-77].

3. This is an extract from the report of the Manager of Federal Crop Insurance Corporation, U.S. Department of Agriculture for 1948.

4. After a thorough study of intensive agricultural development programs in India, Frankel [1971, chapter 7] concludes that the spread of green revolution was of any significance in only areas of favorable agro-climatic conditions. Even in such areas the gains have been very unevenly distributed. For similar conclusions based on empirical analysis, see Bardhan [1974b] and Saini [1976].

5. See Wharton [1969, p. 466].

6. For details, see Ray [1967, pp. 70-71].

7. This practice is notorious for its prevalence in south Asia. For example, if a farmer has three plots of equal size and three sons, usually he divides all the three plots among his sons instead of assigning one to each.

8. This is very common in India.

9. The classical source of this view is Marshall [1956, p. 644].

10. Cheung [1969], Bardhan and Srinivasan [1971], Rao [1971], Stiglitz [1974], Hsiao [1975] and Reid [1977] are some of the important examples.

11. Innovative farming is the best example for such dynamic inefficiency. Empirically this is verified by Rao [1973].

12. This is reported in Ray [1967, p. 33]. This may be mainly due to the optional nature of U.S. crop insurance program and the relatively specialized nature of U.S. farming. Comparatively rich farmers join the insurance to protect their large investments in specific crops.

13. See, for example, the report of the Expert Committee on Crop Insurance in India [Government of India, 1972, p. 23].

14. This is a rationale of wider significance, which is often called upon as a justification for the operation of private and public enterprises simultaneously in various sectors of the Indian economy, for example.

15. This is an extract from the report by Sir William Beveridge on Social Insurance and Allied Services, prepared for the British Government in 1942, as reproduced in Ray [1967, p. 224].

16. They are Brazil - coffee crop insurance, Jamaica - banana crop insurance, Mexico - crop-loan insurance and Sri Lanka - paddy crop insurance.

17. See Government of India [1972].

18. For theoretical and empirical support, see Botts and Boles [1958] and Dandekar [1976] respectively.

19. See Dandekar [Ibid, p. 72].

20. Elected body of village representatives in India.

21. See Dandekar [Ibid, p. 80].

22. See footnote 11.

CHAPTER VI

SUMMARY AND CONCLUSIONS

In the preceeding chapters we were concerned with the role and significance of uncertainty due to natural hazards, on peasant behavior. An attempt was made to show that if peasants are considered as essentially operating under conditions of uncertainty, most of the apparently irrational behavior could be given economic rationalization. Many traditional practices and institutions have been shown to be manifestations of rational decisions in the face of uncertainty by poor farmers who are basically risk-averse.

As the largest economic sector, agriculture can play a key role to achieve the objectives of economic growth and social justice in most developing countries. However, from a careful scrutiny of the developmental efforts during the last quarter century, one gets the impression that agriculture was relatively neglected. Further, whenever there were development programs directed at agriculture, the benefits have in general accrued to a minority of wealthy farmers. Thus most of the economic development bypassed a significant segment of the population, namely peasantry, which constitutes more than sixty percent of the population in most of these countries. That is, the majority still remain largely outside the entire development effort, neither able to contribute much to it, nor benefit fairly from it. Apart from the staggering human misery involved, this has created acute social tensions within and between regions and countries which threaten the very foundations of civilization.

An important aspect of peasant life is the uncertainty of income due to the vagaries of nature. This uncertainty plays a critical role in peasants' decision-making. Any serious attempt at explaining peasant rationality and formulation of economic policies for the uplift of the peasantary should take this important factor into consideration.

A simple decision model of a typical peasant farmer, facing output uncertainty is introduced in chapter two. Making the reasonable assumption of risk-aversion, we establish that it is quite a rational decision on the part of a small farmer to employ less of each variable input than classical marginal analysis would suggest. Also, the observed inverse relationship between farm size and productivity is given a theoretical support. That is, in labor intensive farming there are no economies of scale; rather there are diseconomies of scale. This has important implications in the context of land reforms.

A common complaint about small farmers is regarding their reluctance to adopt modern techniques and inputs of farming. Analyses based on deterministic models have practically no explanations for this phenomenon. But in the context of the present model, this reluctance can be explained as a manifestation of risk-averse behavior of poor farmers. To encourage them to adopt innovative farming, the most effective public policies are shown to be those directed at reducing the riskiness of farming.

In most developing countries, there is some sort of urban income taxation, but usually there is no similar tax on agricultural incomes. Extension of income tax to agriculture is usually resisted on grounds that this may adversely affect agricultural production. But the present analysis clearly indicates that this need not be the case. Rather, introduction or increase in the existing level of taxation may encourage the farmer to work harder. Indeed, these results are extensions of similar results in the analysis of taxation and risk-taking.

In section 4 of chapter two we generalize the model to include input uncertainty also. Instead of assuming that inputs are committed before farming and hence are not subject to uncertainty with the weather, it is more realistic to assume that the farmer adjusts his decisions regarding the application of inputs as the weather uncertainty unfolds itself through planting, weeding and harvesting seasons. Moreover, there are other random factors affecting the flow of different inputs. With this realistic generalization, which substantially complicates the model, the above analysis is repeated. The result is that in a number of cases it is required to impose rather restrictive assumptions regarding farmer's risk-behavior to arrive at difinitive conclusions.

Chapter three deals with the specific problem of rural-urban migration. For this, we introduce a modified version of the model of chapter two. The standard theory of rural-urban migration in traditional economies treats the wage income as uncertain, assuming that the farm income is certain. We are looking at the problem from the opposite side, that is, stressing the role of uncertainty in farm income. Within this framework, we analyse the peasant household behavior as regards to migration. The effects of a number of public policies including investment in agriculture, land reform, and income tax, on migration are studied.

Perhaps the most significant policy conclusion emerging from the present analysis is the great difficulty of substantially reducing migration without a concentrated effort at making rural life more attractive in the sense of reducing uncertainty in farm income. Unless the risk of farming is substantially reduced or transferred from the farmer through a process of social risk-taking, the peasants will continue to move to the urban areas even if there is no institutionally fixed high minimum wage. Also, our analysis reinforces the original Harris-Todaro [1970] conclusion that economist's standard policy prescription of generating urban employment opportunities through the use of 'shadow prices' implemented by means of wage subsidies or direct government hiring might, in fact, exacerbate the problem of urban unemployment and underemployment. We tend to agree with Todaro [1976, p. 222]: There would thus appear to be no strictly urban solution to the urban unemployment problem. Rural development is essential.

In the earlier chapters, we were concerned with the implications of uncertainty on peasant decisions and the impacts of certain public policies on them. Some of these policies have direct bearing on elimination or reduction of the impact of uncertainty. But elimination or reduction of agricultural uncertainty may not be always feasible or desirable. In such cases, as Arrow [1971, p. 143] argued, the best solution would be to transfer the risk to an agency best able to bear this risk. The social and private benefits of such risk-transfer may well exceed the costs. This is quite true in the case of much of the traditional agriculture, most of which heavily depends on the vagaries of the weather.

Taking these facts into account, we devote chapter four to develop a theory of crop insurance within a general equilibrium framework. We begin by clarifying certain conceptual and analytical issues which demonstrate the need for a separate theoretical analysis of crop insurance apart from the standard economic theory of insurance. Then we provide certain theoretical justifications for the non-existence of competitive crop insurance markets. And finally, a theoretical model of public crop insurance is developed and its properties analysed.

In chapter five we discuss the role of insurance in general, and crop insurance in particular. Also, the distinct problems of crop insurance are presented and the traditional insurance surrogate institutions and practices discussed. Further, a viable crop insurance program specifically, in the context of India, is developed.

As should be expected of any theoretical study of this kind, which involves a number of simplifying assumptions, the policy conclusions are of general nature. Results are not developed to the level of policy prescriptions, but rather, to the more modest goal of providing a better understanding of the implications of various public policies under uncertainty. Also, since the earlier parts of the study are restricted to partial equilibrium models, the welfare implications of various public policies cannot be fully pursued. Further, in order to concentrate on the significance of output uncertainty due to natural hazards, the role of price uncertainty was completely left out.

However, as a first major attempt at analytically exploring the implications of uncertainty on various aspects of peasants' decision-making and in bringing out the internal contradictions involved in pursuing policies based on deterministic models in a world of uncertainty, the present study is hoped to have served a purpose.

Possible suggestions for further research are several. First, partial equilibrium models of farm-production and migration may be extended to general equilibrium models of at least two-sector framework. Labor-leisure choice may be an important aspect of peasant life. And the models might be extended to include this aspect of decision-making. The analysis can be further extended by including savings and assets and intertemporal utility maximization.

And finally, most of the policy conclusions emerging from the present analysis critically depend on the specific risk-behavior of the peasants. The relevant hypotheses need empirical testing, specifically in the context of peasant decision-making.

APPENDIX

SOME TOOLS IN THE ANALYSIS OF BEHAVIOR UNDER UNCERTAINTY

Uncertainty affects virtually every aspect of economic life. Yet, economic analysis of decision making under uncertainty started only recently. The basic problem in designing probabilistic models to cope with uncertainty is that one need not only take into account the random variables and associated probability distributions, but the decision-maker's attitude towards risk must also be taken into consideration. Thus, in order to determine the extent of a manufacturer's investment in a new venture, or to find if it will ever be undertaken, one must not only assume knowledge on the part of the producer of the probability distributions of the unknown variables, but also know whether he has aversion, indifference or preference for the risk involved.

A.1. The Von Neumann-Morgenstern Utility Function

A simple method to deal with these problems is suggested by the Von Neumann-Morgenstern utility theory, which is closely related to the probability theory. This approach, however, rests on various behavioral postulates, implicit in a set of axioms underlying the existence of the Von Neumann-Morgenstern utility function. The acceptance of this utility function implies acceptance of the axioms, which were lucidly explained by Von Neumann and Morgenstern [1947] and subsequently by Marschak [1950].

Once we accept the existence of a utility function, the formal characterization of the decision-maker's risk attitude in terms of the properties of the utility function can be easily accomplished. Suppose that the utility function of income, Y,

$$U(Y) \qquad \text{(A-1)}$$

is thrice differentiable. Confronted with a choice of two policies, each of which determines Y as a random variable, an individual is supposed to choose that policy which makes E[U(Y)] the larger, where E is expected value in the sense of probability-theory.

One can always assume that income is desirable; that is

$$U'(Y) > 0 \qquad \text{(A-2)}$$

Thus U(Y) is a strictly increasing function of Y. If U(Y) satisfies the axioms of Von Neumann-Morgenstern utility theory, then the sign of the second derivative of U(Y), U"(Y), determines the individual's attitude towards risk. Specifically, if U"(Y) = 0, so that the utility function is linear, the individual is indifferent or neutral towards risk. In that case it can be easily seen that maximization of expected utility of income and expected income are identical. If $U''(Y) > 0$, so that the utility function is strictly convex, the individual is said to have risk-preference. And finally, if $U''(Y) < 0$, so that the utility function is strictly concave, the individual is risk-averse.

A.2. Risk-Aversion

From the time of Daniel Bernoulli on, it has been common to argue that (1) individuals tend to display aversion to taking risks, and (2) that risk-aversion in turn is an explanation for many observed phenomena in the economic world. The proposition that risk-aversion is the prevalent phenomenon has been supported by personal introspection, consideration of the well-known St. Petersburg paradox[1] and its success in explaining various economic phenomena such as insurance, common stocks and other risk-sharing contracts and holding of money in preference to interest-bearing securities.

A risk-averter is defined as one who, starting from a proposition of certainty, is unwilling to take a bet which is actuarially fair. Consider an individual with income Y_0 who is offered a chance to win or lose an amount h at fair odds. His choice is then between the certain income Y_0 and a random income taking on the values Y_0-h and Y_0+h with probabilities 1/2 each. A risk-averter by definition prefers the certain income; by the expected utility hypothesis, we must have

$$U(Y_0) > 1/2\ U(Y_0-h) + 1/2\ U(Y_0+h)$$

which can be rewritten as

$$U(Y_0) - U(Y_0-h) > U(Y_0+h) - U(Y_0)$$

Thus the utility difference corresponding to equal changes in income decreases as the income increases which implies that $U'(Y)$ is strictly decreasing as Y increases. That is, for a risk-averse individual

$$U''(Y) < 0 \qquad \text{(A-3)}$$

A related concept is 'risk premium'. If a person is risk-averse, his risk premium is defined as the difference between the expected value of the return from the risky prospect and its certainty equivalent.[2] Let

$$U(Y^*) = 1/2\ U(Y_0-h) + 1/2\ U(Y_0+h)$$

Here $\pi = Y_0 - Y^*$ is defined as the risk premium.

A.3. The Arrow-Pratt Risk-Aversion Functions

While the mere existence of risk-aversion can be used as an explanation of the existence of insurance, and other institutions, one needs a suitable measure of risk-aversion to develop more specific results. The rate of change of $U'(Y)$, namely $U''(Y)$ cannot be taken as a measure of risk-aversion as the utility function is unique only up to positive linear transformation and $U''(Y)$ is hot scale-invariant. Considering this, Arrow[3] has defined two simple measures of risk-aversion as

$$R_A(Y) = \frac{-U''(Y)}{U'(Y)} \quad \text{(A-4)}$$

$$R_R(Y) = \frac{-U''(Y)Y}{U'(Y)} \quad \text{(A-5)}$$

The former is called a measure of absolute risk-aversion and the latter a measure of relative risk-aversion.

The two measures have simple behavioral interpretations. Consider an individual with wealth Y who is offered a bet which involves winning or losing an amount h with probabilities p and 1-p, respectively. The individual will be willing to accept the bet for values of p sufficiently large and will refuse it if p is small (a risk-averter will refuse the bet if p = 1/2 or less). The willingness to accept or reject a given bet will in general also depend on his present wealth. Given the amount of the bet h and the wealth Y, there will, by continuity, be a probability p(Y,h) such that the individual is just indifferent between accepting and rejecting the bet. If attention is restricted to small values of h, the function p(Y,h) can, for fixed Y, be approximated by a linear function of h, which turns out to be,

$$p(Y,h) = \frac{1}{2} + \frac{R_A(Y)}{4} h + \text{terms of higher order in } h \quad \text{(A-6)}$$

The absolute risk-aversion directly measures the insistence of an individual for more-than-fair odds, at least when the bets are small.

If one measures the bets not in absolute terms but in proportion to Y, the absolute risk-aversion is replaced by the relative risk-aversion. Denote the amount of the bet by kY, where k is the fraction of wealth at stake; if one lets h = kY in (A-6) and uses the definitions (A-4) and (A-5), one gets

$$p(Y,kY) = \frac{1}{2} + \frac{R_R(Y)}{4} k + \text{term of higher order in } k \qquad \text{(A-7)}$$

Another similar interpretation of the risk-aversion measures has been developed independently by John Pratt[4] in terms of the risk premium. Consider an individual faced with a random income Y and offered the alternative of a certain income, Y_0. A risk-averter would be willing to accept a value of Y_0 less than the mean value, E(Y), of the random income. His risk premium is defined as

$$\pi = E(Y) - Y_0$$

Then, if the distribution is sufficiently concentrated (technically if the third absolute central moment is sufficiently small compared with the variance), Pratt shows that

$$\pi \doteq \frac{1}{2} \sigma^2 R_A(Y_0) + \text{terms of higher order} \qquad \text{(A-8)}$$

where σ^2 is the variance of Y. A similar interpretation can be offered for the relative risk-aversion. Thus the risk premium increases proportionately with the value of the risk-aversion function.

Arrow argued that absolute risk-aversion is a non-increasing function of wealth. This hypothesis is quite appealing, because it implies that, as income increases, the individual's willingness to engage in small gambles of a fixed size does not decrease. After all, as the individual gets richer, one should normally expect a decline in his risk-aversion or in his risk-premium. But as Mossin [1968] points out, in itself the hypothesis of decreasing absolute risk-aversion is just a formalization of a certain property of a preference ordering. As such it leaves a good deal to be desired in the way of meaningfulness. It is only when its implications for behavior in a wide variety of circumstances are explored that its usefulness is established. But in general, it has withstood the empirical tests. Arrow showed that non-increasing absolute risk-aversion implies that risky investments are not inferior goods.

The relative risk-aversion is the elasticity of the marginal utility of wealth; it is invariant not only with respect to changes in the units of utility but also with respect to changes in the units of income. Arrow hypothesized that the relative risk-aversion is a non-decreasing function of wealth. This implies that if both the size of the bet and wealth are augmented in the same proportion, the willingness to accept the bet does not increase. In the context of the portfolio model, this hypothesis implies that non-risky investment is a luxury good.

A.4. Changes in Riskiness or Uncertainty

An interesting question in probabilistic economics concerns the implications of a marginal change in riskiness or uncertainty. For this type of analysis, one must agree on a self-consistent and intuitively appealing definition of a change in the degree of uncertainty. One measure of riskiness which suggests itself is the variance of the random variable. In some circumstances, however, the variance becomes a self-contradictory measure of uncertainty.[5]

Another objection frequently voiced against the use of variance as a measure of risk concerns the use of the mean-variance analysis approach with which this measure is invariably associated. In the mean-variance analysis, the decision-maker facing risk is assumed to be aware of efficiency frontiers between the expected value of the random variable and its variance. However, the efficiency frontier of the mean-variance hypothesis is not necessarily equivalent to that of the expected utility approach. Furthermore, the mean-variance analysis is invariably illustrated with the aid of a quadratic utility function, which has an objectionable property in that it gives rise to an absolute risk-aversion function which is strictly increasing in wealth. And we have already argued that the absolute risk-aversion is realistically a non-increasing function of wealth or income.

Rothschild and Stiglitz [1970, 1971] analysed the general problem of ordering uncertain prospects and the measurement of risk. The measure of riskiness that we used in the text has been called by Rothschild and Stiglitz a 'mean-preserving spread'. In this measure, a small increase in riskiness or uncertainty is defined by the stretching of the original density function of the random variable around a constant mean.

Let the random variable be denoted by r. In terms of the mean-preserving spread, the increase in riskiness may be defined as follows. Let us write r^* as

$$r^* = \delta r + \theta$$

where δ and θ are two shift parameters, and initially $\delta = 1$ and $\theta = 0$. The variance of r^* is given by

$$V(r^*) = V(r)\delta^2$$

where $V(r)$ is the variance of r. The expected value of r^*, on the other hand is given by

$$E[r^*] = \delta E[r] + \theta.$$

It is clear that an increase in δ above its initial value of unity leads to an increase in the variance as well as the expected value of r^*, whereas a rise in θ above its initial value of zero causes only a rise in $E[r^*]$. Thus, in order to restore the original mean of r^*, an increase in δ should be matched by a decline in θ by an amount such that $dE[r^*] = 0$, or

$$dE[r^*] = E[r]d\delta + d\theta = 0, \text{ so that } \frac{d\theta}{d\delta} = -E[r].$$

An increase in uncertainty in terms of the mean-preserving spread is then defined by $d\delta > 0$ and $\frac{d\theta}{d\delta} = -E[r]$.

Footnotes

1. For a complete and lucid statement of the paradox and its implications, see Samuelson [1977].

2. Certainty equivalent is that level of sure income at which the individual is indifferent between the risky prospect and the sure income.

3. These risk-aversion functions were independently developed by Arrow [1965] and Pratt [1964] and are usually known as Arrow-Pratt risk-aversion functions.

4. See Pratt [Ibid, pp. 124-26].

5. See Rothschild and Stiglitz [1970, pp. 241-42].

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