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RISK AND ADOPTION OF HYBRID MAIZE IN EL SALVADOR

An enduring concern in economic development is the extent to which risk impedes adoption of new technologies and slows the rate of yield expansion in the production of food crops. Almost by definition, poor farmers in developing countries are associated with a reluctance to take risks, presumably because risk taking would jeopardize their subsistence. This association implies that low-income farmers will not change their more stable, lower-return traditional techniques for riskier, more profitable practices and varieties. What J. A. Roumasset (1979c) calls the conventional wisdom that risk retards adoption has been proposed in several variations, and it seems to have lasting appeal in the development literature. Several contributors to a book edited by C. R. Wharton, Jr. formally advanced the risk-inhibits-innovation hypothesis in 1969, J. C. Scott constructed a political theory of moral economy on the subsistence ethic in 1976, and J. K. Galbraith in 1979 concluded that aversion to risk represents an important explanation for poverty in the developing nations.

Until recently, knowledge about the relation among poverty, risk, and adoption was founded on a concensus of speculation, casual observation, and hypothetical intuition. In the last ten years, speculation has gradually given way to an embryonic but rapidly expanding body of empirical measurement. This paper begins with a brief summary of some of the recent empirical work relevant to risk and the development and transfer of technology. The discussion in the survey embraces two risk-related issues confronting practitioners who make "microscopic" decisions on technological policy in developing countries. Should technical scientists in national agricultural research programs design fundamentally different technologies to accommodate different risk attitudes of farmers? Should corrective policy such as a crop insurance scheme be carried out when the adoption of technical recommendations falls short of expectations? The literature review accents some of the dimensions to these questions and thus builds an analytical framework for a case study on risk and adoption of maize

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(corn) hybrids by low-income farmers in El Salvador. After a description of maize varietal innovation and diffusion in El Salvador, the measurement and analysis of risk attitudes and perceptions among adopters and nonadopters of maize hybrids are highlighted in the paper.

In order to place this study in the context of other field research on risk and adoption, it is useful to contrast what is analyzed and is not analyzed in terms of technology, time, and location. The case study focuses on the adoption of a step in technology, not on a package of practices; on who ultimately adopts, not on who first adopts; and on weather-induced yield risk in rainfed agriculture, not on price risk.

RISK, ADOPTION, AND TECHNOLOGICAL POLICY

What does the descriptive empirical literature on risk and adoption imply for the design and transfer of technology in developing countries? Some would say that the answer is "not much" since researchers in the area cannot even agree on how to define risk (Roumasset, 1977). Risk is a complex topic rich in technical jargon—it cuts across many disciplines including economics, statistics, and psychology.[1] Progress toward a consensus is further obscured by the tenacity with which economists cling to differing schools of thought. In the recently published papers (Roumasset et al., 1979) from a conference on risk and agricultural development, it is fairly easy to identify participants with prior theoretical commitments to either security-based or expected utility views of the world.[2]

The measurement difficulties encountered in descriptively testing the relative merits of the two theories are formidable.[3] Each choice model contains a number of working parts which tend to mask what actually drives the model into making predicted choices. Moreover, it is not evident that finding one theory to be a more accurate approximation to reality is relevant to many issues on technological policy. This paper argues that it is more productive to break down security-based and expected utility models into their principal components, risk attitudes and risk perceptions.

Risk Attitudes

Most descriptive research on adoption of technology and risk has focused on risk attitudes which refer to the farmer's evaluation of the desirability of what happens when he or she adopts a practice or variety. Three views probably span the positions taken in the literature on the relative importance of risk attitudes.

[1] H. P. Binswanger (1978b) provides a description of choice models popular with different disciplines. J. R. Anderson (1979) presents a taxonomy of decision models used by economists to comply with predictive, analytical, and normative purposes.

[2] The two decision-theoretic approaches are sharply contrasted in Chapter 2 of Roumasset (1976). Subjective expected utility models are examined in depth by Anderson et al. (1977).

[3] Few attempts have been made to positively pit one theory against the other. W. R. Lin's research on six commercial farmers in California is one of the few rigorous tests of the two classes of models. The information required for Lin's test included yield and price distributions by commodity, elicited utility functions, disaster levels, threshold probabilities, and lexicographic orderings on goals.

The first position argues that aversion to risk constitutes an impediment to adoption and results in a lower level of resource use than would otherwise prevail in a risk-neutral world.[4] What distinguishes this view from others is an advocacy approach for remedial technological policy. Thus, proponents of this view maintain that fairly simple procedures are available to develop proxy measures for risk attitudes that are unobservable. It is therefore feasible to correlate risk attitudes reflected in these measures with socioeconomic traits (Moscardi, 1976; Moscardi and de Janvry, 1977).[5] This correlation can permit the design of technology to match the risk preferences for different groups of farmers according to their socioeconomic characteristics. For instance, a significant correlation between a risk attitudinal index and farm size would suggest different recommendations for large and small farmers.

The second view acknowledges the role of risk aversion in underinvestment in technical change by farmers, but does not put forward second-best policy prescriptions only because of this recognition. This policy stance stems from Binswanger's innovative application of an experiment to measure risk attitudes among low-income farmers in India. The experiment consists of a series of games in which participants choose among alternatives and thus reveal their preference among tradeoffs between expected returns and variance.[6] Binswanger (1978a, 1980) found that the vast majority of farmers are intermediately to moderately risk averse and that it would take an immense change in any one socioeconomic trait to switch individuals from one risk-attitude category to another. Binswanger (1977) concludes that "it clearly makes no sense to advocate the development of technologies which differ in their riskiness so that small farmers adopt the low-yield, low-risk ones whereas large farmers adopt the high-yield, high-risk ones" (p. 30). Emphasis is placed on finding the source of risk aversion and on objectively measuring the benefits and costs of institutional policies to diffuse risk.

The third position is diametrically opposed to the first and argues that "the *a priori* assumption that risk aversion of low-income farmers causes serious resouce misallocation has no theoretical or empirical basis" (Roumasset, 1979a, p. 63). What appears to the superficial observer to be risk aversion is often grounded in an alternative rational explanation. In response to imperfections in

[4] Given a risk-averse decision maker, it is easy to show this implication in the context of a static neoclassical production environment using expected utility maximization as a choice criterion (Magnusson, 1969). K. J. Arrow and C. R. Lind have also provided a theoretical justification for the view that it is in the interest of society that individuals act as profit maximizers.

[5] C. H. Gladwin (1979) and D. A. Sillers (1980) provide good critiques of the E. R. Moscardi and A. de Janvry approach (1977).

[6] The experimental games approximate on-farm decision making by giving farmers time (at least one day) to reflect on their decisions. Some games are "real" as the participants are paid the outcomes of their choices. A criticism that is frequently voiced of the experimental method is that the participants never lose the games. At least in theory, subjecting farmers to games with losses may be self-defeating. If losses are sufficiently large, credit constraints may influence choices and thereby lead to biased estimates on preferences. Sillers (1980) in a recent application of the experimental approach in the Philippines circumvented some of these difficulties by distributing money to farmers which they staked to play games with real gains and losses.

capital and product markets, cropping decisions by farmers may point to risk-averse behavior when in reality their actions are guided by an underlying set of risk-neutral preferences (Roumasset, 1979c). For example, R. T. Masson (1972) has shown that a divergence in borrowing and lending rates in capital markets can induce risk-averse behavior for one-period gambles for farmers who are risk-neutral in lifetime consumption.[7] Roumasset's basic contention is that all too often analysts fall back on the crutch of risk aversion to explain lagging adoption when they should be probing the impact of fragmented and incomplete markets.

Risk Perceptions

Applied economists have—and not without some justification—largely neglected descriptive research on risk perceptions among low-income farmers in developing countries.[8] Risk attitudes are often associated with permanence and thus are of analytical interest from a policy perspective. In contrast, perceptions of yield risk are specific to a particular technique, location, and time. There also exists a well-knit body of economic theory to suggest hypotheses about risk attitudes. Microeconomic theory on the development and transfer of information is rapidly emerging, but is not nearly as well-developed. Finally, most field research indicates that risk perceptions are as difficult to measure as risk attitudes.

Despite these limitations, the scant economic literature that is available on the impact of risk perceptions on adoption of technologies is more harmonious. There appears to be a growing awareness that risk perceptions are important (Roumasset, 1979a). The literature on farming-systems research stresses the need for a communion in perceptions among farmers, extensionists, and researchers (Hildebrand, 1977). On-farm testing is increasingly emphasized so that perceptions converge more rapidly on the expected profitability of new technologies under farmers' agroclimatic and socioeconomic conditions. If risk perceptions markedly condition adoption, it becomes imperative to know what farmers perceive as the source of risk, how their perceptions are formed and change, and how their subjective judgments compare to "objective" measurement.[9]

In much of the literature, attitudes, perceptions, and choice criteria are lumped together under the title of risk. O'Mara's work (1971) represents one of

[7] A prominent source of confusion in expected utility theory pertains to the time horizon and the carriers of value in the utility function. Most theoretical work uses wealth as an argument, while almost all positive measurement is carried out on gains and losses. In theory, if decision makers are characterized by a stable utility function over time and evaluate prospects in terms of their final states of wealth, measuring utility with respect to a wealth index such as net assets or with respect to changes in net assets should lead to identical results. In practice, experimental evidence strongly suggests that subjects do not integrate assets, but rather evaluate risky alternatives with regard to perceived gains and losses (Kahneman and Tversky, 1979; Binswanger, 1978b; and Sillers, 1980). This finding is also supported in the present study and clearly underscores the need to understand what farmers perceive as gains and losses when they are faced with new technological options.

[8] Studies by Gladwin (1977), Roumasset (1976), and O'Mara (1971) are the exception.

[9] In this paper, "objective" refers to measurement based on historical data.

the few efforts to formally weigh the relative significance of risk attitudes and risk perceptions as determinants of adoption. In studying the diffusion of a package of improved practices in maize production under irrigation in Mexico, O'Mara found that first-degree stochastic dominance prevailed in 55 out of 66 cases; that is, 55 farmers perceived that the distribution of returns to one technique was equal to or everywhere superior to that of another technique. Therefore, for more than 80 percent of the farmers risk attitudes and choice criteria were irrelevant in the decision to adopt the new maize technology. The results from the O'Mara study underline the simple observation that a perception of risk is a necessary condition for the emergence of risk attitudes and choice criteria as impediments limiting adoption.

With regard to the transfer of technology, it is not sufficient to show that farmers are risk-averse and hold risky perceptions to recommend institutional policy that tries to correct for the supposed negative influence of risk aversion. One also has to demonstrate that there are substantial benefits in moving from a risk-averse to a risk-neutral position (Roumasset, 1979b).

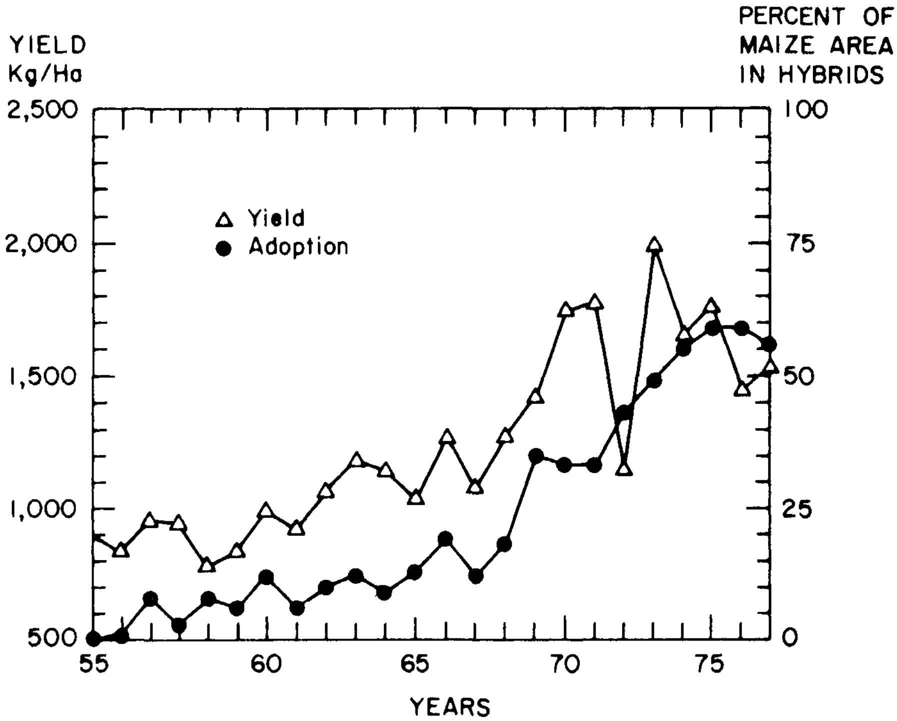
MAIZE HYBRIDS IN EL SALVADOR

The development of maize hybrids in El Salvador is one of the underpublicized success stories of increasing food-crop productivity of low-income farmers through adaptive agricultural research. Maize is the staple food crop in El Salvador, particularly in the rural areas, and is produced throughout the country. Over 90 percent of maize output is produced under rainfed conditions with about 90 percent of area planted at the start of the rainy season in May. Farms under 5 hectares account for about 75 percent of production (El Salvador, 1974).

Historically, the maize improvement program in El Salvador has had two assets — continuity and dedicated plant breeders. Maize breeding started in 1947 when researchers at the Centro Nacional de Agronomia, a precursor of the modern-day Centro Nacional de Tecnologia Agropecuaria (CENTA), collaborated with plant breeders working in the Rockefeller Program in Mexico. In the early 1950s the principal breeder, Jesus Mario Argueta, changed the focus of the program from the selection of improved open-pollinated varieties to the development of hybrids. Argueta had a high school education, a shoestring budget, and an innate ability to select promising lines. In 1963, he released a double-cross hybrid (H-3) which increased yield potential over local varieties by about 2,500 kilograms per hectare. Compared to the indigenous varietal types, H-3 is more fertilizer-responsive, has about the same level of disease and insect resistance, has good food quality and post-harvest characteristics, and is later-maturing. However, H-3 is more precocious than improved lines previously introduced from outside El Salvador. A slightly later-maturing hybrid (H-5) with enhanced yield potential was released in 1965.

The government embarked on a massive fertilizer demonstration campaign to promote the new technology. The campaign was based on a complementary package of divisible seed, fertilizer, and insecticide and on the same extension

CHART 1.—MAIZE YIELDS AND ADOPTION OF HYBRIDS IN EL SALVADOR*



* Data from El Salvador, Ministerio de Agricultura y Ganaderia, *Anuario de Estadisticas Agropecurias*, various years.

methodology used to diffuse maize hybrids in Iowa in the 1930s. Over 18,000 demonstration plots were planted in El Salvador in the late 1960s (Birdsall, 1967).

In most regions, the yield advantage and economic superiority of maize hybrids held up in farmers' fields and resulted in the speedy adoption and diffusion of the new technology. By 1973, 50 percent of maize area was planted to hybrids, and accounted for 70 percent of production. Data from 1961 and 1971 Census suggest that the increase in production was shared by all farm-size classes, especially small and medium-sized landholders.[10] The gains in production over the decade were equivalent to a 6.7 percent annual increase in productivity.

After this impressive record, the prospects for continued expansion in output of the country's staple food crop dimmed. The adoption of hybrids has stood at 55 percent of planted area, and yields did not continue their upward trend after 1973 (Chart 1).

[10] 1961 and 1971 were years of comparable weather.

Like many other high-yielding biochemical innovations introduced during the late 1960s, regional differences in resource endowments have conditioned the adoption of maize hybrids in El Salvador. The 1971 Census data showed that regional levels of adoption by number of maize farmers varied from 73 percent in Santa Ana in western El Salvador to only 4 percent in Morazon in eastern El Salvador. Explanations for such regional discrepancies in adoption performance are not readily apparent. El Salvador is about the size of Massachusetts and has adequate marketing infrastructure. Maize is produced under rainfed conditions throughout the country, and total growing season rainfall is not significantly different among regions. The International Maize and Wheat Improvement Center (CIMMYT) adoption study based on a sample of 350 maize farmers in 1972 did not offer definitive conclusions on socioeconomic or agroclimatic determinants of adoption, but suggested that restricted access to institutional credit could be a constraint (Cutie, 1975).

A futher analysis of the CIMMYT data suggests that environmental variables such as soil and daily rainfall indices more adequately explain adoption behavior than socioeconomic and institutional variables like farm size, access to credit, schooling, and tenure (Walker, 1980, ch. 3). The location-specific incidence of drought stress is the most likely explanation for regional differences in the rate of hybrid adoption. Water balance estimates show that regional drought stress was severe in 1972, 1976, and 1977 when national average yields were low (Chart 1). Although total growing season rainfall is more than sufficient, rainfed maize planted in May in El Salvador is extremely susceptible to drought stress during tasseling and silking in July. In some years, July is punctuated with an extended drought called a *canícula* which inflicts crop damage, particularly in northeastern El Salvador where rainfall distribution is erratic, soils are shallow and stony, and maize is planted on highly sloped land. The drought stress hypothesis is reinforced by yield estimates from farmers and from CENTA extensionists (CENTA, 1977a, 1977b).[11]

It is important to recognize that the nature of varietal risk induced by drought is different from risk usually associated with the adoption of other input recommendations such as fertilizer application levels. Many farmers in El Salvador have adopted some components, such as fertilizer, of the technology package extended in the 1960s, but have rejected maize hybrids. For these farmers, the adoption of hybrids does not lead to greatly increased financial risk. Although hybrid seed on a per unit basis is three to four times costlier than local seed, seed costs represent a relatively small proportion of cash expenses. Thus, varietal risk primarily refers to pure yield risk which is conditioned by interactions between varietal characteristics and the environment.

Assuming that drought stress is the major source of risk, three perceptions may affect the decision to adopt. Nonadoption may be grounded in the belief that the incidence of drought stress is high, and there is little, if any, relative advantage of hybrids over local varieties. Nonadoption could also stem from a perception that

[11] Other sources of crop loss include weeds, corn stunt disease in the coastal areas, and a few pests, such as fall army worm and white grub. Unlike drought stress, these yield reducers can usually be controlled by management practices.

local varieties withstand drought better than hybrids. Nonadopters may believe that earlier maturing local varieties are more effective in escaping drought.

Regional differences in risk attitudes may also contribute to regional adoption behavior (Binswanger, 1977). For historical sociocultural reasons, farmers in areas lagging in adoption may be more risk-averse or they may value consequences differently than farmers in other regions. These hypothesized regional differences in beliefs and attitudes of adopters and nonadopters are analyzed in the next section.

DESIGN OF THE FIELD WORK AND RISK ATTITUDES

The two villages selected for study correspond to two regions where farmers have roughly equal access to input and output markets, where the agroclimatic environments appear to be alike, but where the levels of hybrid adoption are significantly different. Farming systems studies by R. Rodriguez et al. (1978) and M. Juarez et al. (1979) indicate that the cropping systems practiced by farmers in Las Peñas in northcentral El Salvador and in La Trompina in the northeast are similar and representative of a wider geographic area. In both villages, maize is planted in May, and sorghum is interplanted when maize is first weeded in early June. Fertilizer use is widespread.[12] Dosage, type, date, and form of application do not vary appreciably between the two sites. Farmers in the two villages rely on small hand tools for planting and cultivation. Yet despite these similarities, the studies showed widespread adoption of hybrids in Las Peñas compared to total rejection of hybrids in La Trompina.

Farmers in the two villages have access to credit and information on varieties. Many small farmers in both areas have used institutional credit provided by the Agricultural Development Bank to purchase inputs, particularly fertilizer. Both areas are serviced by extension agencies located less than 15 kilometers from the village. The first and second extension agencies in El Salvador were founded in 1951 in towns not far from the two villages.

Tabulated secondary data do not suggest a significant difference in agroclimatic variability between the two areas. Land in both sites is classified as class VII which is marginal for production of annual crops. Maize is planted on hillsides that average more than 25 percent in slope. Mean annual rainfall is estimated at 1,538 and 1,959 millimeters for the stations closest to Las Peñas and La Trompina, and July rainfall averages 285 and 236 millimeters (El Salvador, 1979). CENTA plant breeders view both areas as drought prone, and they planted regional variety trials of 21 cultivars in both sites in 1978.

The field work consisted of a series of nine repeated interviews to elicit risk attitudes, assess risk perceptions, and canvas socioeconomic characteristics of farmers in the two villages. Attitudes were measured by experiment and by direct-interview. A budget limitation on the payoffs in the experimental games constrained the sample size to about 20 farmers per village.[13]

[12] Although fertilizer application per cultivated hectare is high in El Salvador, most nonadopters of maize hybrids apply less fertilizer than the interviewed farmers.

[13] The expected value of winnings from the games was slightly higher than the average weekly wage for a hired agricultural laborer in El Salvador.

Farmers were selected at random from a census listing of farmers in the two villages. The original list was revised by village leaders to include only those who planned to plant maize in May 1979 and who were readily accessible for the sequence of interviews. Farmers were also screened to determine if they could distinguish the agronomic characteristics of local and hybrid cultivars. From the 45 farmers initially interviewed in both villages, 42 participated in the experiment, two did not want to cooperate, and one could not verbally identify the agronomic traits of the hybrid.

Questioning in the interviews was unstructured and conversational. In order to reduce nonsampling error, the study was carried out with one team of four interviewers. With the exception of the final survey, the author was present during each on-farm visit. No visit lasted more than an hour. The sequence of interviews took about six weeks in each village.

The 21 farmer participants in La Trompina planted only local varieties in 1978. All participants in Las Peñas planted H-3 or H-5 in 1978.[14] Farmers in both villages are primarily subsistence cultivators; the median size of the May planting was less than two hectares in 1978.

The Experiment

The type and sequence of experimental games played with farmers in El Salvador were patterned after Binswanger's application of the experimental methodology to measure risk preferences of farmers participating in the International Crops Research Institute for Semi-Arid Tropics (ICRISAT) village-level studies in India. The origin, structure, and analysis of the games are described in Binswanger (1977, 1978a, and 1978b).

Although the basic structure of the games is the same, some modifications were introduced to adapt the Indian experiment to conditions in El Salvador. The game involved a choice among eight alternatives — denoted by the first eight letters in the Spanish alphabet: A, B, C, CH, D, E, F, and G. The alternatives were listed from A to G on pages which were distributed to farmers. Figure 1 shows the payoff structure for the eight alternatives in the .50-colon game.[15] The outcome of each game was decided on the toss of a coin. Choice of the A alternative resulted in a gain of .50 colons for either heads or tails (Figure 1). The A alternative represented a sure prospect and was equivalent to not risking anything. At the other extreme, selection of the G alternative yielded a gain of two colons for heads and zero colons for tails. Changing choice from A to G represents a tradeoff in expected value for variance.

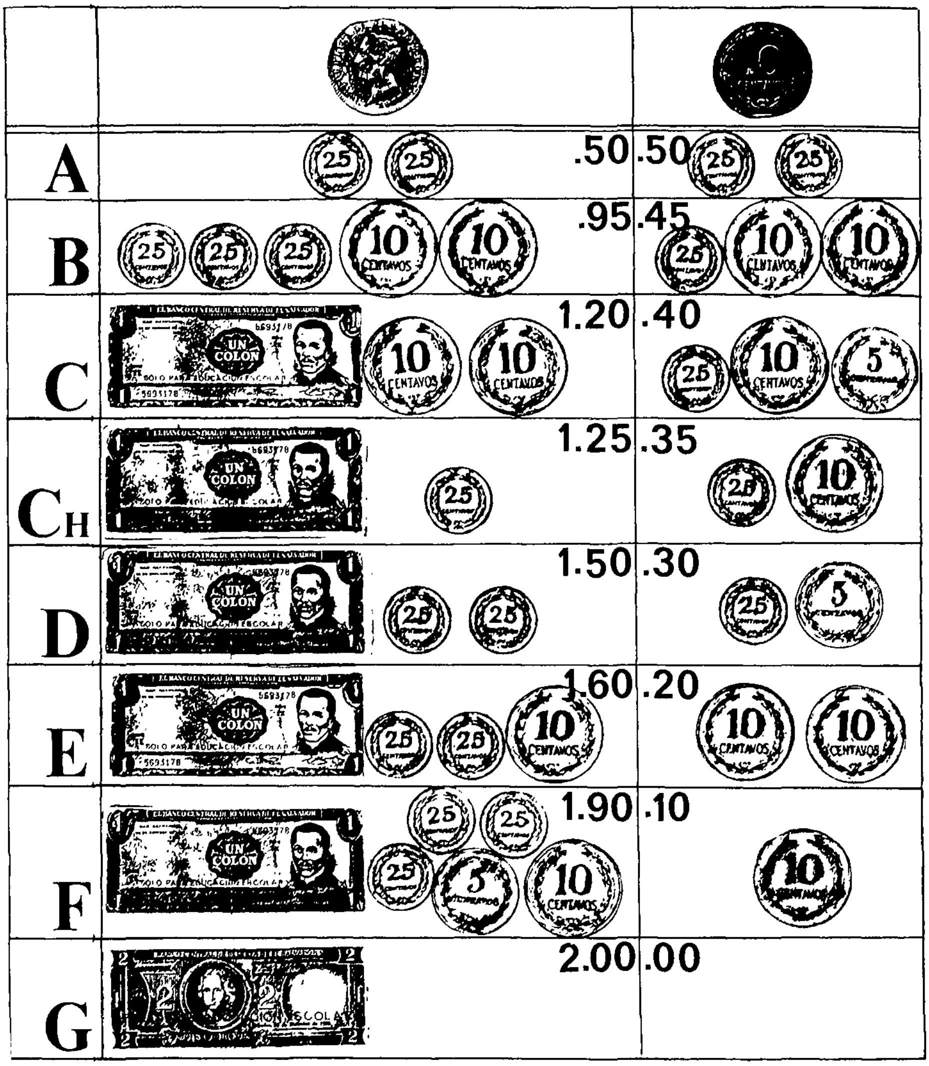
Stochastically inefficient alternatives, CH and E, were included in the games to determine if farmers could discriminate efficient from inefficient choices.[16] Alternatives CH and E have the same expected value but a greater variance than choices C and D.

[14] One farmer in Las Peñas divided his maize planting between hybrid and local varietal types. A few farmers in Las Peñas also planted small plots equivalent to less than 10 percent of their area to local varieties. These plantings were mainly used for seed propagation and for on-farm consumption as roasting ears in early August.

[15] One colon exchanged for $.40 U.S. in El Salvador in 1978.

[16] The games in India were played with one inefficient choice (Binswanger, 1978a).

FIGURE 1.—STRUCTURE OF THE .50-COLON GAME



In order to analyze quantitatively the level of risk aversion associated with each choice, it is necessary to scale the alternatives listed in Figure 1 into a cardinal index. One convenient index used by Binswanger is a partial risk-aversion coefficient denoted by S. Higher values for S are consistent with increasing levels of risk aversion. Depending on the value of the S index, Binswanger has verbally cataloged the choices in the game. Farmers who choose A are characterized as displaying extreme risk aversion; farmers who select G are labeled as showing risk neutrality or even a preference for risk.

In terms of the A alternative, game sizes of .50, 5, 10, and 50 colons were played in El Salvador. Farmers were paid the outcomes in five .50-colon games, in one 5-colon game, and in one 10-colon game. Hypothetical games included one 5-colon game, one 10-colon game, and two 50-colon games.

Farmers liked the games. When asked why they had chosen an alternative, farmers usually responded with proverbs. Choice of the A, B, or C alternatives was frequently accompanied by the statement that "too much ambition breaks the bag," which means that when a farmer puts too much grain in his bag, the bag may rip causing a loss of grain. For the selection of F and G alternatives, farmers often asserted that it was necessary to take a risk to make a gain.

Most farmers had a general feeling for the purpose of the games, but probably did not have a clear understanding of the specific objectives of the experiment. They looked upon the different components of the experiment as challenges or puzzles. Judging from their comments solving the puzzles of the games was easiest, and assessment of risk perception most difficult.

Empirical distributions of risk attitudes by village are tabulated in Table 1 for the last three real games. For the .50-colon game, many farmers chose the slightly risk-averse and risk-neutral alternatives F and G. As the size of the game increased, farmers switched to the moderately and intermediately risk-averse alternatives C and D. These results are consistent with Binswanger's findings that most farmers display intermediate or moderate aversion to risk and that farmers become more risk-averse as the size of the game increases. The data in Table 1 do not suggest that nonadopters are significantly more risk-averse than adopters.

The Direct Interview Approach

Risk attitudes of farmers were also assessed by the certainty-equivalence approach which is the method most commonly used to elicit utility functions. A certainty equivalent is the value of a sure prospect which makes a decision maker indifferent between it and a risky bet. In order to measure pure risk attitudes, the risky bet is always represented by a 50–50 gamble.

Application of the certainty-equivalence approach in El Salvador built on the farmers' knowledge of the experimental games. It is doubtful that the participants could have responded to the hypothetical questions without the use of visual aids or without having played the games. Farmers were told that it was necessary to play a different type of game because in the earlier games they always won, and information on losses was also required. Farmers were presented with a cardboard paper displaying the A alternative, the sure prospect, and the G alternative, the risky prospect (Figure 2). The payoff of the G alternative was initially set at 1,000 colons for heads and 0 colons for tails. An arbitrary amount such as 300 colons was chosen for the sure prospect whose value in play money was placed under the heads and tails columns opposite the A alternative in the upper half of Figure 2. The farmer was asked whether he would choose A or G. If he chose A, the value of the sure prospect was decreased. Eventually, a point of indifference (X_1) was obtained to the nearest ten colons. The value of X_1 was then placed as a payoff under the heads column for the G alternative, and the questioning was repeated until a second certainty equivalent was defined. The third point of indifference evolved from a payoff structure with 1,000 colons and the value of X_1 in the heads and tails columns, respectively, for the G alternative.

TABLE 1.—DISTRIBUTION OF RISK AVERSION BY VILLAGE AND SIZE OF GAME

Village	Size of game in colons (and number)	Aversion to risk in percent[a]						
		Extreme A	Severe B	Inter-mediate C	Moderate D	Slight F	Neutral to negative G	Inefficient E, CH
Las Peñas[b]	.50 (5)	5	10	5	14	24	24	19
La Trompina[c]	.50 (5)	5	10	10	14	19	24	19
Las Peñas	5.00 (7)	19	10	19	24	5	10	14
La Trompina	5.00 (7)	5	5	19	43	5	5	19
Las Peñas	10.00 (10)	5	14	19	19	24	5	14
La Trompina	10.00 (10)	0	0	24	38	10	14	14

[a] Rows may not total to 100 percent because of rounding.

[b] Adopters.

[c] Nonadopters.

A similar procedure was used with the lower-half of Figure 2 to elicit four points on the negative branch of the utility function.

The estimates of risk attitudes measured by the certainty-equivalent approach contrast sharply with the experimental results. The certainty-equivalent estimates show that eight farmers were extremely venturesome as their certainty equivalents approached the value of the favorable outcome for the risky prospect for both gains and losses. Two of these farmers expressed a preference for risk for the sake of gambling so that they could continue to play the game when the value of the certainty-equivalent exceeded the payoff from the favorable outcome. The linear segmented utility functions of the remaining 34 farmers in Chart 2 show that the prevailing functional form is S shaped characterized by concavities in gains, convexities in losses, and discontinuities about the reference point zero. Few, if any, of the utility functions graphed in Chart 2 are strictly concave. The overwhelming majority display convex segments, particularly for losses. The tendency for steepness in the utility function about zero suggests that most farmers are extremely risk-averse for small changes in income.[17]

Differences in Risk Attitudes Between Adopters and Nonadopters

The hypothesis that nonadopters are more risk-averse than adopters is tested by regressing a set of personal characteristics on risk-aversion indices estimated by the experimental and direct-interview methods. The dependent variable for the experimental game regressions is $\ln$ S.[18] The index of risk aversion for the direct-interview data is the risk premium which is defined as the difference between the expected value of the risky bet and the certainty equivalent. Risk premia characterized by positive, zero, and negative values signify risk aversion, neutrality, and preference. Regressions are estimated for risk premia on gains and on losses. Two regressions are also estimated for the experimental data; one uses the responses given in games 2–11, and the other uses information on the last six real games.[19]

Village is entered as a dummy variable in the risk-attitude regressions. Las Peñas is assigned a value of one, La Trompina a value of zero. Because the depen-

[17] This S-shaped functional form of the utility function is commonly found in descriptive work using a certainty-equivalence approach. O'Mara (1971) estimated similar results and Masson (1974) argued that those results suggested a security-based or more general bounded-rationality behavior. A much more plausible explanation is supported by experimental research by psychologists (Kahneman and Tversky, 1979). They find that subjects systematically make choices on perceived changes in wealth irrespective of their current asset position. Most of the experimental evidence indicates that subjects respond more to differences in small changes than equal differences in large changes. Thus, "the difference in value between a loss of 100 and a loss of 200 appears greater than the difference between a loss of 1100 and a loss of 1200" (Kahneman and Tversky, p. 278). This psychological response could partially explain the estimated steepness of the utility about the zero reference point and apparent risk-seeking behavior over the negative domain.

[18] This dependent variable is chosen so that results can be compared with Binswanger's (1978a) study. Numerical values of $\ln$(S) associated with the different alternatives correspond to the same study.

[19] The first game was introductory and yielded a higher estimated variance than the other games. In fact the first game gave results consistent with what one would expect with a single-interview where the reflection and reinforcement effects are absent.

FIGURE 2.—VISUAL AID USED TO ELICIT RISK ATTITUDES BY THE DIRECT INTERVIEW APPROACH

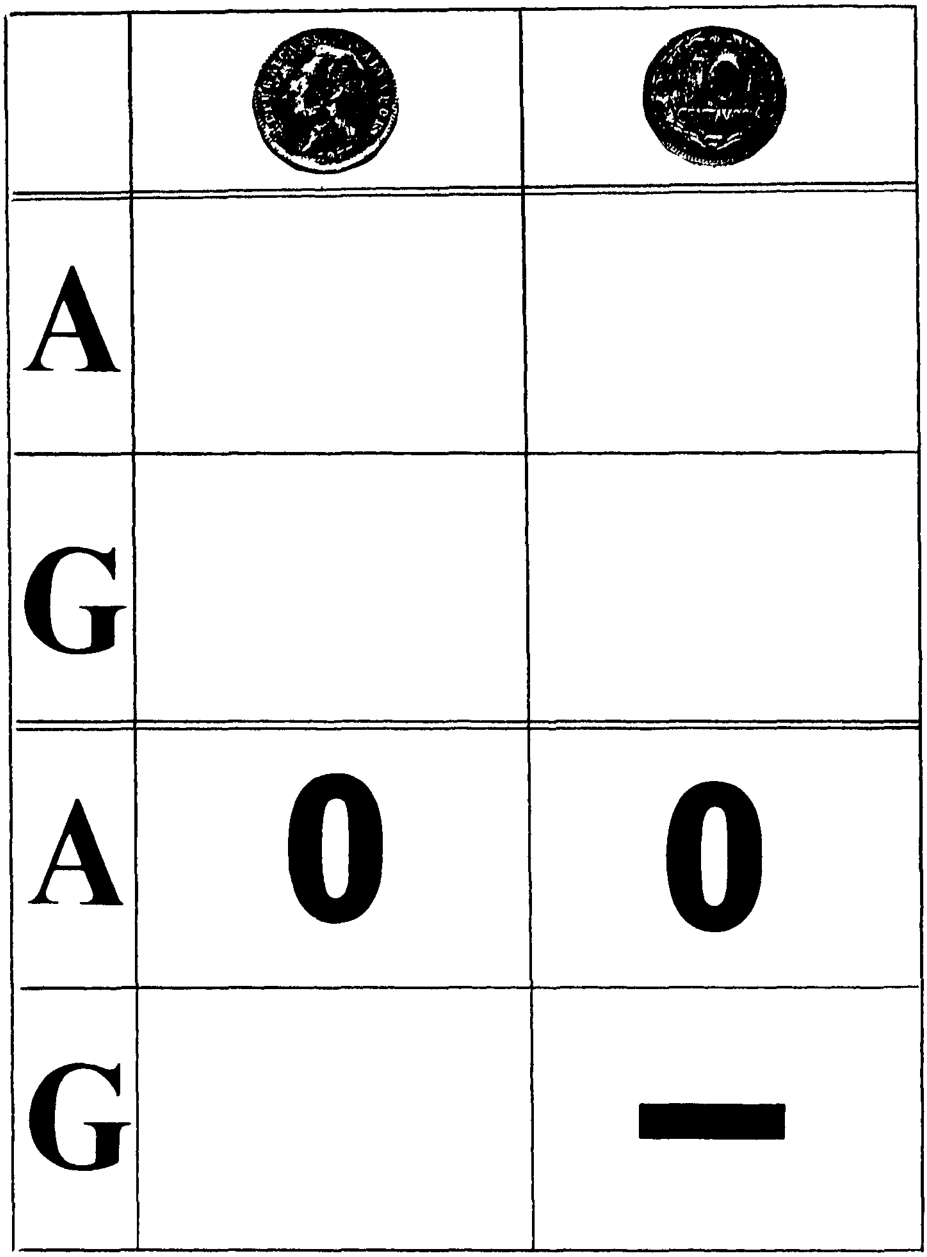
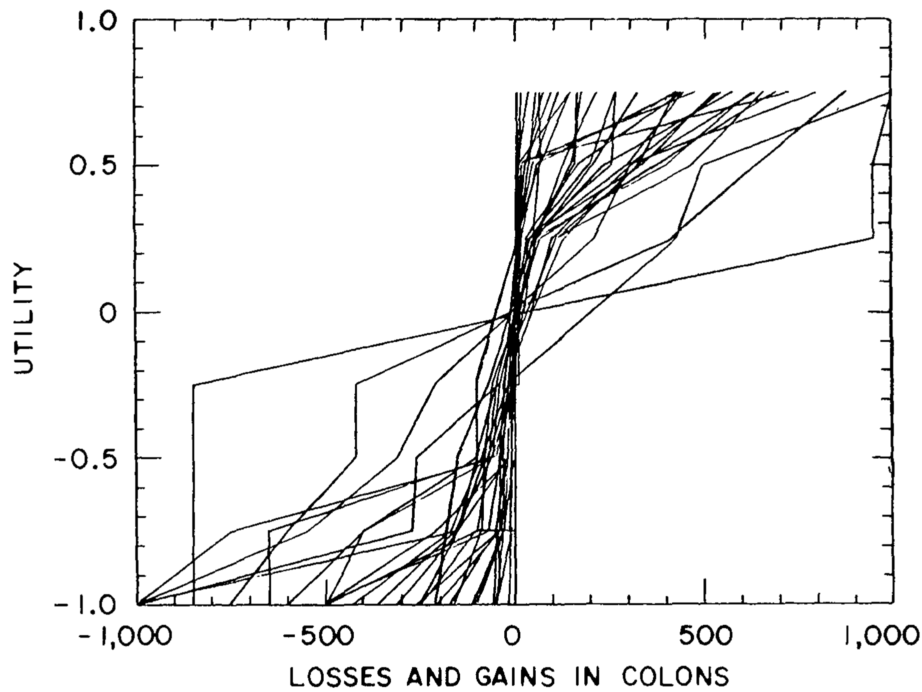


CHART 2.—ESTIMATED UTILITY FUNCTIONS OF FARMERS IN EL SALVADOR*



* Based on direct interview approach. See text.

dent variable *ln* S and the risk premia are larger for higher levels of risk aversion, the expected sign of the estimated coefficient for village is negative if, ceteris paribus, adopters are less risk-averse than nonadopters.

A description of the explanatory variables with the expected signs for their coefficients is given in Table 2. Schooling, gambling, assets, off-farm income, and the number of working-age adults per family are expected to be negatively associated with risk aversion. Age and tenurial insecurity should be positively correlated with risk aversion.[20]

For the experimental data, the size of the game, the type of game (real versus hypothetical), and luck in previous games are included as explanatory variables. The 5-, 10-, and 50-colon games are specified by dummy variables as the reference size of game for the regressions is .50 colons.[21]

[20] Binswanger (1978a) provides a brief discussion on the reasons for including each of these variables in the regression and hypothesizes on their expected interaction with pure risk attitudes.

[21] Running the regressions with all the information from the games provides an explicit test for increasing partial risk aversion. The results are not significantly different when separate regressions are estimated for each size of game.

TABLE 2.—DEFINITIONS AND EXPECTED SIGNS OF THE EXPLANATORY VARIABLES IN THE RISK-ATTITUDE REGRESSIONS

Explanatory variable	Definition	Expected sign
Village	0 = La Trompina, 1 = Las Peñas	–
Age	Head of household, in years	+
Schooling	Head of household, in years	–
Gambler	0 = did not buy a lottery ticket in 1978 1 = bought a lottery ticket in 1978	–
Assets	Total value of physical assets, in 1,000 colons	–
Tenure	0 = owner-operator 1 = fixed-cash renter	+
Off-farm income	In 1,000 colons	–
Working-age adults	Working-age adults, as percent of total family members	–
Luck	Number of wins minus losses in previous games	–
Size of 5, 10, and 50-colon games	0 or 1 for each	+
Hypothetical or real games	0 = real games 1 = hypothetical games	–

The results from the games regressions presented in the first two columns of Table 3 show that personal characteristics are not highly correlated with measured risk attitudes. Although most of the signs of the estimated coefficients are consistent with expectations, the independent variables do not explain much of the variation in risk preferences. The coefficients for the size of game variables are significant and are consistent with the earlier observation that farmers shifted to more risk-averse choices in the larger-sized games. Education is another significant explanatory variable and may be related to the ability to process information in picking alternatives with a higher expected value. Contrary to expectations, the sign of the estimated coefficient on village is positive and significant indicating that a change from the village on nonadopters to the village of adopters is characterized by an upward shift in the level of risk aversion, i.e., nonadopters are less risk-averse than adopters.

The regression on the positive branch of the utility function (Col. 3) explains (for cross-sectional data and a small sample) a considerable share of the variation in risk attitudes elicited with the direct-interview approach. As expected, the propensity to gamble and the total stock of physical assets are negatively correlated with risk aversion. A third potentially significant variable is village. But whatever the village dummy variable is measuring does not support the hypothesis that nonadopters are more risk-averse than adopters.

The explanatory power of the regression on losses (Col. 4) is nil. The absence of correlation is most probably explained by measurement error associated with the certainty-equivalence approach in describing risk attitudes on losses.

If differential risk attitudes are encountered, the results from both methods of measurement weakly suggest that nonadopters are less risk-averse than adopters. One is forced to conclude either that pure risk attitudes by themselves do not explain differential rates of adoption of hybrid maize in El Salvador or that the methods used do not capture the true attitudes of the two populations of farmers.

These results are not surprising. The survey data suggest that the risk attitudes observed in the games and interviews are conditioned by a restricted set of alternatives which are available to small landholders and fixed-cash renters to adjust to risk. The measured attitudes do not vary significantly in the two villages because the mechanisms used by farmers to adjust to risk are the same in both villages.[22]

RISK PERCEPTIONS

This section analyzes whether risk perceptions differ between farmers in the two villages. The source of risk is assumed to be drought stress. The incidence of drought, varietal resistance to drought, and varietal ability to escape drought are potentially important considerations conditioning varietal choice. Subjective perceptions of these components of risk were assessed and compared to "objective" measurement whenever historical rainfall and agronomic information was available.

The interviews were carried out in April and May, at the time of maize planting, and farmers were especially interested in talking about the weather—particularly the prospects for a *canícula* in 1979. Inevitably, the conversation would lead to an unsolicited expression by farmers of belief in a cyclical rainfall pattern. Based on past experience the farmer would contend that three good

[22] Farmers in both villages rely on participation in the casual labor market particularly in the harvesting of export crops, on livestock sales, and on informal consumption loans to adjust to risk. The rapid diffusion of small storage bins among low-income maize farmers has recently contributed to improved risk management.

TABLE 3.—CORRELATION OF RISK AVERSION WITH PERSONAL CHARACTERISTICS BY MEASUREMENT METHOD*

Explanatory variable[a]	Experimental games[b]		Direct interviews[c]	
	Games 2-11	Real games	On gains	On losses
Constant	−1.15	−1.14	180.42	215.71
	(−2.17)	(−1.70)	(.75)	(1.40)
Village	.71	.79	337.95	11.39
	(2.84)	(2.39)	(2.96)	(.16)
Age	.01	.022	−4.55	−2.04
	(1.00)	(1.69)	(−.94)	(−.66)
Schooling	−.21	−.34	−53.31	−13.94
	(−2.33)	(−3.09)	(1.31)	(−.53)
Gambler	−.10	.12	−240.95	−105.06
	(−.42)	(.39)	(−2.19)	(−1.49)
Assets	.001	−.003	−6.04	−1.07
	(.17)	(−.38)	(−2.15)	(−.59)
Tenure	−.36	−.22	143.06	−11.31
	(−1.33)	(−.63)	(1.14)	(−.14)
Off-farm income	−.13	−.20	2.56	−1.77
	(−1.44)	(−1.66)	(.059)	(−.064)
Working-age adults	−.35	−.81	221.79	260.68
	(−.59)	(−1.07)	(.81)	(1.48)
Luck	−.02	−.02	–	–
	(−.33)	(−.25)		
Hypothetical games	−.35	–	–	–
	(−1.06)			
5-colon games	1.00	1.24	–	–
	(3.03)	(3.35)		
10-colon games	.82	.58	–	–
	(2.48)	(1.57)		
50-colon games	1.01	–	–	–
	(2.35)			
$\bar{R}^2$	.08	.11	.26	.00
F value	2.60	2.94	2.83	1.00
Number of observations	420	252	42	42

*t values of the estimated coefficients are in parentheses.

[a]See Table 2.

[b]Dependent variable is index of risk aversion ($\ln$ S).

[c]Dependent variable is the risk premium.

years are followed by two bad years or x good years precede y bad years. Farmers realized where they were in the cycle and, therefore, had a perception of whether the upcoming year would be good or bad depending upon what had happened in the immediate past. Nevertheless, the responses in the interviews gave the impression that farmers did not appear to act on their beliefs about the weather for the next planting season. Farmers seemed resigned to their fate, hoped for the best outcome, and did not attach a high degree of certainty to their subjective evaluation of the incidence of drought.

Farmers had much stronger opinions on the relative merits of hybrids and local varieties to withstand and escape drought. With the exception of one nonadopter who could not estimate yields for hybrids, most farmers had a clear perception of expected varietal yield for a given duration of drought. Farmers also stressed that for periods of extended drought yields varied somewhat by field and by location within each field.

Incidence of Drought

Individual estimates of the probability of drought were assessed by the visual impact approach (Anderson et al.). Farmers were shown a cardboard paper with matchboxes glued to its surface. Each matchbox represented a fixed interval of consecutive days of drought in July and early August. Farmers were asked to evaluate the relative frequency of drought by placing matches in the boxes corresponding to 0, 8, 15, 22, and 30 days of drought. Each match represented a year.[23]

Table 4 shows that the average perception of the frequency of drought varied markedly between the two villages. Farmers in Las Peñas who have adopted hybrids believed that a drought longer than or equal to 22 days occurred about one year in five. In contrast, a comparable estimate for the village of nonadopters was .42 or about two years in five. The difference in perceptions for adopters and nonadopters for a long drought is statistically significant at the 5 percent level.[24]

The objective probabilities of drought support the beliefs expressed by farmers. These water-balance estimates described in Walker (1980) show that historically drought has been more severe in La Trompina than in Las Peñas. The average subjective probabilities of nonadopters agree with the objective probabilities. In contrast, adopters overestimated the incidence of drought and underestimated the frequency of good years. One cannot infer from the data in Table 4 that the incidence of an extended drought in Las Peñas is zero. Daily rainfall registries are not complete for some years for the station nearest Las Peñas which may be located in a different ecological niche or microclimate than the closest meteorological station. Nonetheless, it is clear that prolonged droughts are more common in La Trompina.

[23] The assessment of the incidence of drought was probably the greatest source of nonsampling error in the field work. Farmers had a definite set of beliefs, but it was difficult to structure those beliefs into a probabilistic mode. Since all farmers were exposed to the same questioning procedure by the author, it is unlikely that interviewer bias is significantly different for the two villages.

[24] Based on a one-tailed Kolmogorov-Smirnov test.

TABLE 4.—AVERAGE PROBABILITIES OF DROUGHT IN JULY AND EARLY AUGUST*

Type of probability, village	Duration of drought, days				
	0	8	15	22	30
Perceived[a]					
Las Peñas	.15	.32	.31	.12	.11
La Trompina	.16	.18	.24	.22	.20
Observed[b]					
Las Peñas	.60	.25	.19	0	0
La Trompina	.15	.15	.23	.31	.15

*Source: See text.
[a]Perceived refers to subjective or personal probabilities.
[b]Observed refers to probabilities calculated from historical rainfall data.

Drought Resistance

Before yields were assessed, farmers were asked how much fertilizer they would apply by variety. More than 90 percent of farmers responded that they would apply two bags (or the equivalent of 400 pounds) of 20-20-0 and two bags of 21-0-0 for both the hybrid and local variety per *manzana*.[25] Farm management surveys also suggest that these quantities represent the modal levels of application of maize farmers in both villages (Juarez et al., 1979; Rodriguez et al., 1978). Although farmers felt that hybrids were more responsive to fertilizer, they believed that their land was so marginal that applying less fertilizer would seriously compromise the yield of either varietal type. Thus, the yield estimates reflect only one idealized technique which is widely practiced by both groups of farmers although minor variations in inputs and cultural practices occur.

Average yield estimates conditional on drought-day intervals show that farmers in the villages of adopters perceived that yields were higher for the hybrid for each state of drought listed in Table 5. The increase in average expected yield attributable to a change from the local variety to the hybrid was 14 quintals per *manzana* or 56 percent.

Adopters did not agree on which varietal type was superior in a canícula. Nine farmers believed that local varieties outyielded hybrids in an extended drought, while the other 12 farmers held the opposite belief. These conflicting beliefs again suggest that long droughts are infrequent in Las Peñas; a blurred percep-

[25] One manzana equals .7 hectares. Yield is measured in quintals per manzana. One quintal contains 100 pounds, and a quintal per manzana is roughly equal to one bushel per acre.

tion of varietal performance in drought is most likely conditioned by the low incidence of drought.

The average beliefs in La Trompina did not reveal dominance of one varietal type. In years of evenly distributed rainfall, farmers perceived that hybrids outyielded local varieties. They contended that in the worst years their variety always gave some grain, while the ears of the hybrids were larger but barren. Many farmers in La Trompina remembered the experience of one farmer who planted H-3 in a droughty year and received a good crop of fodder but no grain. This belief was reinforced by similar experiences of other farmers in neighboring villages. The superiority in average expected yield of the hybrid variety was only 15 percent. Yield perceptions were also significantly different at the 5 percent level for the two groups of farmers.

The average expected yields for both varietal types, particularly the hybrid were higher in Las Peñas then in La Trompina. This subjective yield advantage probably reflects objective site-specific conditions, namely the higher fertility and greater field capacity of soils in Las Peñas. Objective information from on-farm experimental data is not available to confirm or deny the yield perceptions of farmers. After the hybrids were released in 1965, local varieties were no longer included as a check in regional variety trials. The 1978 on-farm trials provided little information on drought resistance as rainfall was abundant and consequently hybrids outyielded local varieties in both villages.

Drought Escape

Several questioning procedures were attempted to measure the perception of varietal potential for drought escape. In general, farmers in La Trompina believed that the shorter physiological cycle of the local varieties constituted a definite advantage. In contrast, farmers in Las Peñas seldom referred to the drought-escaping potential of local varieties as an important attribute. A suitable framework was not found to quantify this belief; consequently, the potential for drought escape by varietal type was assessed from "objective" measurement through weighted drought-stress indices developed by R. H. Shaw (1977). These estimates suggest that the earlier-maturing local varieties enjoy a slight edge over hybrids in escaping drought in La Trompina, but have no advantage in drought escape in Las Peñas (Walker). Even in La Trompina the potential for drought escape cannot be fully exploited because of the erratic nature of the canícula.

Unlike estimated risk attitudes, the risk perceptions for the two groups of farmers are clearly different. On average, nonadopters believe that drought is more intense in their village, local varieties are superior to hybrids in withstanding a 30-day drought, and local varieties are characterized by a greater potential to escape drought.

EFFICIENCY COST OF RISK AVERSION

Having documented risk-averse attitudes and risky perceptions among the nonadopters of maize hybrids, this section looks at the productivity gains one could envisage if risk aversion was removed as an obstacle to adoption. The size

TABLE 5.—AVERAGE ESTIMATED YIELD BY VILLAGE, VARIETY, AND DAYS OF DROUGHT*
(Quintals per manzana)

Village and variety	Days of drought, in July and early August: 0	8	15	22	30	Weighted average[a]
Las Peñas						
Hybrid	52	47	37	26	12	39
Local	34	33	26	17	8	25
La Trompina						
Hybrid	44	40	25	12	1	23
Local	34	32	22	13	5	20

*Source: See text.
[a]Average expected yield across farmers.

of the underinvestment caused by farmer risk aversion in hybrid maize focuses on comparing theoretical predictions with actual choices. The test is divided into five steps: (1) transformation of yield distributions to net return distributions; (2) screening of varietal techniques for first-degree stochastic dominance; (3) specification of choice criteria; (4) comparing predicted and actual choices from subjective and objective perceptions; and (5) calculating the benefits from corrective policy.

The policy importance of farmer risk aversion is supported if the following interrelated conditions are true: first-degree stochastic dominance does not prevail for many farmers, risk-averse decision rules achieve a higher predictive success rate than a norm of profit maximization, and the increase in net returns accompanied by nonadopters switching from local varieties to hybrids is substantial. If any of these conditions is false, then it is assumed that the existence of risk aversion does not imply significant second-best economic inefficiency.

In testing for first-degree stochastic dominance and in comparing the predictive power of choice criteria, the decision is defined over two acts. The farmer can either plant all of his fields to the hybrid or to the local variety. This specification does not correspond well to the diffusion of a new innovation, but it is consistent with the adoption of a mature innovation and with the observed behavior of farmers in the two villages. Moreover, the decision analysis is carried out in discrete form for all choice criteria. With the exception of the lexicographic ordering rules, the reference area for all farmers is a maize planting of one manzana. This area approaches the modal acreage planted to maize in May for farmers in both villages.

Generating Net Return Distributions

The first step involves a linear transformation of yield estimates to net returns. It is assumed that the grain from the two varietal types is characterized by identical output price distributions.[26] Since harvesting and on-farm transport costs depend on the level of yield, these expenses are subtracted from the farm-gate price to arrive at an average field price.

Different cost levels for the two techniques are attributed to the higher cost of hybrid seed. Seed costs are also weighted to reflect replanting costs for each farmer.

Combining the information on output price and costs gives the net return relation R_{ijkl} for drought state i, varietal type j, and farmer k located in village ℓ. Fixed costs are defined as those expenses which do not vary with the change of technique and include the costs of labor and other inputs such as fertilizer. Fixed costs are allowed to vary between villages to reflect regionally different opportunity costs for agricultural labor in 1978 (Alvarado et al., 1979). With the exception of labor, the distributions of input prices are assumed to be identical for both villages. Costs of capital and land are not included so that the concept of returns used in the analysis represents net returns to capital, land, and management.

Screening for First-Degree Stochastic Dominance

The two varietal-return distributions for the farmers in both villages are screened for first-degree stochastic dominance.[27] First-degree stochastic dominance is based on the weak assumption that decision makers prefer more net returns to less. If one variety "dominates" another, then choice criteria and risk preferences are immaterial for the decision on varietal choice.

From the 41 farmers who provided information on the yield consequences for the two varieties, the hybrid dominates the local variety in the sense of first-degree stochastic efficiency for 12 farmers. Since these farmers, who believe that the hybrid outyields the local variety in every state of drought, came from the village of adopters, the predicted choices are consistent with actual choices.

For the remaining 9 farmers in Las Peñas and for all 20 farmers in La Trompina, the cumulative distribution functions for the two varieties crossed at least once. Therefore, there are 29 farmers for whom the different choice criteria can be used to make nontrivial predictions.

Description of Choice Models

For these 29 farmers, decisions on varietal choice are predicted according to four classes of choice criteria. The first criterion is the maximization of expected profitability which is algebraically equivalent to

$$\max_{j} \sum_{i} P_j(\Theta_i) R_{ij}, \qquad (1)$$

[26] These assumptions on input and output price distributions are supported by the surveys and farm management studies by Rodríguez et al. (1978) and Juarez et al. (1979).

[27] The farmer who could not provide yield estimates for the hybrid was excluded from the analysis.

where $P_j(\Theta_i)$ is the subjective probability of drought state i for variety j.[28]

The second class comprises expected utility maximization on net returns. The general rule involves choosing the variety with the highest expected utility value as in (2),

$$\underset{j}{\text{Max}} \sum_i U(R_j/\Theta_i)P_j(\Theta_i) \, . \tag{2}$$

Expected utility maximization is carried out on information from the experimental games and the direct interview approach.[29]

The third class of criteria encompasses further tests for stochastic efficiency. Second-degree stochastic efficiency is frequently equated to risk aversion and is based on the joint assumptions that the utility function is monotonically increasing and is strictly concave (Anderson, 1974). No prediction on varietal choice is made for cases where third-degree stochastic dominance does not hold.[30]

The last class of choice criteria pertains to decision rules suggested by behavioral theory based on bounded rationality. Lexicographic ordering rules and a criterion prescribed by the CIMMYT Economics Manual I (Perrin et al., 1976) are the two classes of bounded-rationality criteria used in predicting varietal choice.

The lexicographic ordering rules LSF1 and LSF2 exemplify safety-first and safety-fixed behavior (Roumasset, 1976). Under both rules the farmer maximizes expected net returns subject to the chance constraint that the probability that expected returns fall below a disaster level is less than or equal to a target probability. Both the disaster level and target probability are exogenous. LSF1 and LSF2 differ in their guidelines for decision making when the chance constraint is not met. LSF1 treats the disaster level as a variable for maximization, while LSF2 regards the probability of falling below the disaster level as a variable for minimization.[31]

[28] Separate drought probabilities are attached to each variety to reflect the potential to escape drought.

[29] For the experimental information, a constant partial risk-averse utility function is used to evaluate choices. Since u (R_{ij}) is not defined for values of R_{ij} less than or equal to zero, a constant is added to each R_{ij} so that evaluation is restricted to the positive domain. Values for S are taken from choices recorded in the highest real game of 10 colons. For the interview information, expected utility is calculated through linear interpolation on the piece-wise utility functions plotted in Chart 2.

[30] Discrete stochastic dominance criteria implicitly operate on the principle that "the tail wags the dog." If one variety is inferior to another in the worst state of the world then stochastic dominance criteria will never choose the same variety irrespective of its relative superiority in other states of the world. Meyer has proposed a bounded form of efficiency criteria which eliminates the problem of indeterminate choice, but raises a new problem of what is an appropriate set of bounds (Robinson and King, 1978).

[31] The lexicographic rules are applied rather narrowly. The targeted disaster level is interpreted in a subsistence sense and represents the quantity of maize in quintals needed to satisfy 65 percent of a family's annual caloric requirement. Caloric requirements are estimated for each family according to family size, age, and sex according to the FAO energy guidelines adjusted to reflect the weight for age data from dietary surveys for El Salvadorean males and females from rural areas. The target level of probability is set at 25 percent for all families. Other income is not included as returns to the planting of maize varieties is maximized subject to the chance constraint.

The CIMMYT rule also represents behavior characteristic of bounded rationality by specifying a target level of marginal returns and a minimum probability of falling below a level of net returns. Strictly interpreted, this choice criterion says choose the higher cost alternative, i.e., the hybrid, when the marginal rate of return on investment exceeds 40 percent and when the area under the lowest 25 percent of the net returns probability density for the hybrid is greater than or equal to the equivalent area for the local variety. If either of these two conditions is not satisfied, then the lower-cost local variety is chosen.

Comparing Predicted and Actual Choices

A brief examination of Table 6 shows that when subjective perceptions are used, the various choice criteria predict at about the same rate of success, between 55 and 72 percent. In general, bounded-rationality rules outperform the estimated utility functions which, in turn, achieve a higher success rate than profit maximization. Nonetheless, the margin in superiority is not statistically significant.[32]

When predictions are generated by employing objective probabilities on the incidence of drought, the predictive performance of stochastic efficiency criteria and the CIMMYT rule are improved. The rate of success increases to 72 percent for stochastic efficiency criteria and the rate of failure falls to zero, but in 28 percent of the cases no prediction could be made. The CIMMYT criterion correctly predicts 86 percent of the cases and is decidedly superior to predictions based on elicited risk attitudes or on profit maximization. The differences in success rates between profit maximization and the CIMMYT rule employing objective probabilities of the incidence of drought stress are sufficiently large to reject the null hypothesis that the underlying probability of a correct prediction is the same for both criteria. The high rate of success achieved by the CIMMYT criterion and by the discrete stochastic efficiency rules further suggests that farmers are characterized by risk-averse preferences since they appear to weigh heavily consequences of the most unfavorable states of drought.

Compulsory Adoption of Hybrids

What are the benefits associated with enforcing a contract such as a crop insurance program which compels farmers in La Trompina to plant hybrids? If equal weights are assigned to each assessor and both the subjective estimates of yield consequences and the "objective" probabilities of drought are used, the expected benefits from such a program are equivalent to a gain in yield of about 5 percent or about 1 quintal per manzana. Clearly, these benefits, which are calculated under the assumption of perfectly elastic input supplies and output demands, are not large. Moreover, it is unlikely that the small size of the expected benefit stream would be sufficient to cover the costs of a crop insurance program.

[32] The null hypothesis that the probability of a correct prediction is the same for all types of decision models cannot be rejected at the 5 percent level with a nonparametric Cochrane Q Test which is suitable for testing the dichotomized ordinal information presented in Table 6 (Siegel, 1956).

TABLE 6.—ACCURACY OF PREDICTED CHOICE BY CRITERIA AND PROBABILITY ASSESSMENT OF DROUGHT
(Percent)[a]

Choice criteria	Probability assessment of drought: Perceived	Observed
Maximize expected profits	59	55
Maximize expected utility		
Estimated utility functions from the experimental games	66	66
Estimated utility functions from the direct interview approach	59	59
Stochastic efficiency	55[b]	72[c]
Bounded rationality		
LSF1	69	69
LSF2	72	72
CIMMYT criterion	69	86

*Source: See text.
[a]Percent of predicted choices that correspond with actual choices.
[b]No prediction, 36 percent.
[c]No prediction, 28 percent.

One could argue that the perceptions of farmers are wrong, i.e., that the yield consequences for the hybrid are underestimated for the most adverse states of drought. There are no easy answers to this assertion. For example, one maize breeder at CENTA believes that hybrids outyield the local varieties in the northern region in a severe drought, the other two breeders say that the converse is true. In any case, a belief in inefficient or "wrong" perceptions does not call for policies designed to address risk-averse attitudes. If perceptions diverge, then more information is needed.

CONCLUDING COMMENTS

The village-level study of the adoption of maize hybrids in El Salvador indicates that risk attitudes are about the same for adopters and nonadopters, regional differences in adoption are largely explained by differing risk perceptions (which reflect actual risk conditions), and the underinvestment in maize hybrids caused by farmer risk aversion is not great. Clearly, these findings in a study of 42 farmers in El Salvador should be interpreted with caution and do not provide definitive answers to the questions about technological policy that were posed at the outset of the paper. But they can be incorporated into the accumulating body of empirical evidence to outline areas of emerging consensus.

The experimental evidence in El Salvador points to the futility of designing separate technologies with varying levels of risk to conform to what casual empiricism suggests are deep-seated differences in risk attitudes among groups of farmers. The targeting notion is infeasible because most farmers are intermediately to moderately risk-averse and because observable socioeconomic traits are poorly correlated with estimated risk preferences. These results are consistent with Binswanger's findings in India (1980) and are also supported by a recent experimental study by Sillers in the Philippines (1980).

Like other innovation-specific, descriptive studies (Roumasset, 1976); O'Mara, 1971; Gladwin, 1977), risk aversion is not found to be a significant impediment to the adoption of improved technology. Although risk-averse attitudes definitely influence choice, the tendency to take for granted that risk aversion results in misallocation of resources is not warranted. This conclusion is probably not valid for lumpy technologies that greatly increase financial risk; for divisible steps in technology, however, practitioners should not be overly concerned that farmers are risk-averse and that the adoption cycle for an innovation has peaked out at a level significantly less than 100 percent. Practitioners should, however, be worried if they do not have information about farmers' perceptions of consequences from the adoption of recommended technologies and about yield performance in farmers' fields. The moral of the study is not new, but it bears repeating: in order "to get the technology right," one must understand how new varieties and practices interact with agroclimatic and socioeconomic environments. Farmers perceive such interactions, and their perceptions often play the leading role in decision making under uncertainty.

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