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Choice of Technique by Lexicographic Safety First for Peasant Agriculture and Reswitching of Risky Techniques

by

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A number of authors [4,5,9,12,29,37] have found mean-variance analysis inappropriate for agricultural settings and have suggested replacing variance by the probability of falling below some exogenous disaster level as the relevant measure of risk. An interesecting set of authors [5,9,10,12,29,30] have discussed the use of lexicographic ordering (L*-ordering) for models involving decision making under risk.[1] In this paper L*-ordering is used to incorporate risk into a choice of technique model. The algorithm for solving the model turns out to be relatively simple. Nomographs are used to give the solution of the model for numerous risk attitudes for a hypothetical choice of technique problem based on rice production in the Philippines.

Lexicographic Safety First (LSF)[2] is basically chance constrained programming (CCP) supplemented by a prescription of what to do in case the chance constraint is violated for

[1]Halter & Dean [12] and Dillon [9] incorrectly define orderings using "lexicographic utility functions." It is impossible to define a lexicographic ordering by a real-valued function (see e.g., Debreu [8], pp. 72-73).

[2]For a previous discussion of LSF models and their relation to Safety First literature, see Roumasset [30].

by all available choices. Under CCP,[3] the objective function is maximized subject to a chance constraint of the form

$$\Pr.(\pi(x) < \bar{d}) \leq \bar{\alpha}$$

where $\pi(x)$ is the objective function, and $\bar{d}$ and $\bar{\alpha}$ are the exogenously determined disaster and confidence[4] levels respectively. This can also be written as

$$F_x(\bar{d}) \leq \bar{\alpha}$$

where F_x is the cumulative frequency distribution corresponding to the choice variable x. The first LSF model, LSF_1, involves maximizing the expected value of $\pi(x)$ whenever the chance constraint is met and minimizing $F_x(\bar{d})$[5] when it isn't. This can be denoted as follows:

$$\text{Let } V(x) = 1 - \text{Max}\left[\bar{\alpha}, F_x(\bar{d})\right]$$

$$\text{and } W(x) = \left[V(x), \mu, \ldots\right],$$

$$\text{where } \mu = E\left[\pi(x)\right].$$[6]

Our hypothesis is that the lexicographic ordering of the W(x)'s predicts the decision maker's preference ordering of the x's.[7]

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[3] See e.g., Charnes and Cooper [6].

[4] $\bar{\alpha}$ is usually described in Safety First literature as the acceptable probability of failure. "Confidence level" is used here to suggest consonance with statistical inference in conventional decision theory and that the criterion for choosing α is the same as in hypothesis testing--it depends on the consequences of error.

[5] Minimizing $F_x(\bar{d})$ is equivalent to Roy's Safety First [32].

[6] E is the expectations operator.

[7] Since the model has been designed for practical applications, only two dimensions of W(x) have been specified. For an alternate use of lexicographic ordering for decisions under uncertainty, see Encarnacion [10].

LSF_2 is the same as LSF_1 except that it involves maximizing the inverse of the cumulative frequency distribution

$$F_x^{-1}(\bar{\alpha}),$$ [8]

whenever the chance constraint is violated for all available x. LSF_2 can be denoted as follows

$$V'(x) \equiv \text{Min}\left[\bar{d}, F_x^{-1}(\bar{\alpha})\right]$$

$$W'(x) \equiv \left[V'(x), \mu, \ldots\right]$$

where the lexicographic ordering of the W'(x)'s again determines the predicted preference ordering of the x's.

Whether LSF_1 or LSF_2 is more appropriate for a given research problem depends on the nature of regret associated with falling below the disaster level. At one extreme the disaster level is an all-or-nothing proposition where the penalty of falling below that level is the same regardless of how close the outcome is to the disaster level. For situations of this type, e.g., where the penalty is total bankruptcy or death, LSF_1 seems quite fitting. At the other extreme, the disaster level may be associated with some target such that not only missing the target is serious, but the amount by which the target is missed is important as well. In such cases LSF_2 may be preferred.

A Model of Choice of Technique in the Short-Run

Before turning to problem of choice of technique under risk, we shall develop a choice-of-technique model under

[8] Maximizing $F_x^{-1}(\bar{\alpha})$ is identical to the principle introduced by Kataoka [14], applied by Turnovsky [35], and named "Safety Fixed" by Day, et.al. [7a].

certainty.

In this model the alternate techniques under consideration[9] by a decision-maker are represented by a technique matrix of the form:

$$\begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \vdots & \vdots & & \vdots \\ y_{g1} & y_{g2} & \cdots & y_{gn} \\ a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{h1} & a_{h2} & \cdots & a_{hn} \\ \bar{a}_{11} & \bar{a}_{12} & \cdots & \bar{a}_{1n} \\ \bar{a}_{21} & \bar{a}_{22} & \cdots & \bar{a}_{2n} \\ \vdots & \vdots & & \vdots \\ \bar{a}_{m1} & \bar{a}_{m2} & \cdots & \bar{a}_{mn} \end{bmatrix}$$

where y_{ij} is the amount of the ith good produced by the jth technique, a_{ij} is the amount of the flow input i required by

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[9]This is a finite analogue of Day's [7] zone of flexible response.

technique j, and $\bar{a}_{ij}$ is the amount of the ith stock required by the jth technique.[10] Since each column vector represents a discrete technique with specified inputs and outputs, there is no need to assume constant returns-to-scale.

In the short-run, choice of technique is conceived of as pertaining to the forthcoming production period for which some inputs (generally both stocks and flows) are subject to fixed constraints. The researcher has a free hand in selecting the length of the production period and which inputs are to be considered fixed for that period according to the particular choice situation he is studying.

The decision-maker is assumed to choose the technique, j, that maximizes

$$\pi_j = \sum_{i=1}^{g} p_i y_{ij} - \sum_{i=1}^{h} c_i a_{ij} - \sum_{i=1}^{m} r_i \bar{a}_{ij} - \sum_{i=1}^{m} d_i \bar{k}_i$$

subject to

$$a_{ij} \leq k_i, \quad i=1 \text{ to } h \text{ and } \bar{a}_{ij} \leq \bar{k}_i, \quad i=1 \text{ to } m$$

$$\text{for } j=1 \text{ to } n.$$

The p's are per unit gross monetary and non-monetary returns (leaving the researcher the option of including enterprise preferences). The c's are per unit costs of the flow inputs, monetary if purchased and opportunity if provided by the decision making unit. The r's are rents, monetary if actually

[10]For example, the a_{ij}'s included bags of fertilizer, and other inputs entirely consumed within the production period. Stocks include irrigation pumps, human bodies and other inputs that are not wholly consumed within the production period.

rented and opportunity if internally provided.[11] $\bar{k}_i$ is the amount of the ith stock available for the production period and k_i is the maximum amount of the ith flow input that can be used. d_i is per unit depreciation of $\bar{k}_i$. For agricultural production, hired labor is considered a flow input, but family labor is considered a stock. Thus if $\bar{k}_1$ is the stock of family labor, $d_1\bar{k}_1$ is the classical[12] subsistence requirement.

Choice of Technique under Risk

Suppose that π_j, for all j, is not known with certainty. Instead due to uncertainty regarding any subset of the p_i's, y_{ij}'s, c_i's, and r_i's; assume there is a unique frequency distribution for each π_j which forms the basis of the choice of technique decision.[13]

Denoting each technique by the number of its column in the technique matrix, define the set of techniques under consideration as

$$TUC \equiv \{i \mid i=1,\dots n\}.$$

[11] Repair costs resulting from the utilization of internally owned stock are included in opportunity rents (since the decision-maker had the opportunity of saving such repair costs by not employing the stock). Thus the extra feed required for draft animals when they are working is subtracted from gross receipts in arriving at π_j.

[12] i.e., that used by Malthus and Ricardo.

[13] Since the distribution enters the theory exogenously, it would be misleading to claim generality of the theory for uncertainty whether the distribution is considered objective or not. Any theory of uncertainty which relaxes the simplifying assumption of pure risk in a useful way must include some discussion of the nature of uncertainty (e.g., how the subjective probability changes as learning proceeds). The nature of uncertainty is beyond the scope of this paper, hence the use of "risk" in the sub-heading.

LSF_1 then becomes:

$$V_i \equiv 1 - \text{Max}\left[\bar{\alpha},\ F_i(\bar{d})\right], i \in TUC$$

$$W_i \equiv \left[V_i, \mu_i, \ldots\right]$$

where F_i and μ_i are respectively the cumulative frequency distribution function for the ith technique and the expected value of π_i. The predicted preference ordering of the i's is determined by a lexicographic ordering of the W_i's. LSF_2 is similarly adapted.

Algorithms for Rice Production Decision in the Philippines

The Lexicographic Safety First models seem especially appropriate for describing the behavior of low-income farmers due to the stark reality of the "disaster level." Considerable literature has accumulated concerning the behavior of the "subsistence farmer" [15,23,24,36,37] which explores the behavior of the farm household unit that is especially concerned with maintaining some (usually culturally defined) subsistence level-of-living. While this concern is readily incorporated into Safety First models by identifying $\bar{d}$ with the subsistence level, other widely-used models of risky decision making are not so easily adapted.[14] In this section the solutions for the Philippine farmers' choice of technique problem under the different Safety First criteria are

[14] In particular, conventional mean-variance analysis (e.g., Markowitz [20]) must, in the absence of normally distributed returns, assume a quadratic utility function in order to guarantee consistency under the Von Neumann-Morgenstern Postulates [34].

presented for various values of $\bar{\alpha}$ and $\bar{d}$. The presentation also provides an illustration of the empirical application of the Safety First rules including algorithms for the solutions.

Identifying a suitable technique matrix can be done on the basis of a priori consideration of technical information, on the basis of common techniques actually practiced by farmers, or a combination of both. For the application to Philippine rice farming, each technique is described by a vector of multiple inputs and a single output. The input requirements are fixed, but the corresponding rice yield is assumed to be a random variable generated from a known probability distribution. Each farm operator is assumed to apply only one technique to his land and his decision is assumed to be independent of past and future cropping decisions.[15] In addition the returns from one hectare of a farmer's land are assumed to be perfectly correlated with the returns of any other hectare of his land.

Risks in agriculture can be broadly classified as yield risk and price risk. Price risks for both inputs and outputs

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[15] In situations where farmers plant more than one variety, practice multiple cropping, green manuring, crop rotation, intercropping, or any other composite practice, alternate cropping patterns may be represented as single vectors so the method described here is still theoretically applicable. For purposes of the research problem involved here, it is assumed that lowland rice fields will be planted only to rice during the wet season, only one variety and cultivation technique will be chosen by each farm operator, and the wet season planting decision is independent of the dry season choice of technique.

are ignored in this paper for two reasons:

1. Price risk is generally small in comparison to yield risk.
2. Even when there is considerable variation in rice prices, as there has been since the introduction of HYV's in 1966, the high co-variance between the prices of different rice varieities, due to a high elasticity of substitution on the demand side, reduces the role of price va iability in choice of technique.

The main sources of yield risk are weather risk, crop damage risk, and timing risk. Weather risk includes damage from flooding, typhoons, drought, and the lack of a dry spell near harvest time as well as rainfall variability. Crop damage risk denotes the variability of yields associated with the damage from pests, insects, and disease. Timing risk involves losses due to not performing various tasks (e.g., land preparation, application of chemicals, weeding) at the optimal times to the extent that these times are not known with certainty.

Four profitable techniques observed in the Bicol Region during the wet season of 1967 are approximated in Table 1 using conventional cost budgeting techniques. The relationship of Table 1 to the technique matrix is as follows. Fertilizer, other chemicals, seed, non-family labor, and interest are a_{1j}, a_{2j}, a_{3j}, a_{4j} and a_{5j} for $j = M_1, M_2, M_3$ and T. The opportunity rents for family labor, land, farm

Table 1: Technique Choices Available to the Average Operator of Rainfed Rice Land (per hectare): Bicol Region, Philippines*

	IR-5 Improved Techniques			Local Varieties Traditional Techniques
	M_1	M_2	M_3	T
<u>riable Costs</u>				
1. Fertilizer	70	90	120	0
2. Other Chemicals	0	10	30	0
3. Seed	25	25	25	20
4. Non-Family Labor	225	245	260	80
5. Interest	30	40	55	6
<u>turns</u>				
1. Average Yield (cavans per hectare)	70	80	90	32
2. Average Gross Returns @ P16 per cavan	1120	1280	1440	512
3. Variable Costs	350	410	490	106
4. Average Net Returns, π_j, (2-3)	770	870	950	406

ased on cross-section data for the 1967 wet season obtained by the icol Development Planning Board and the <u>IRRI Annual Reports</u>, 1966-70.

animals, and other stocks are assumed to be zero.[16] Average net returns are the expected values of the π_j's. T represents a local variety with traditional techniques. M_1, M_2, M_3 are all high yielding varieties (HYV's) cultivated with increasing levels of fertilizer and other chemicals. Hypothetical probability distributions for each technique are shown in Figure 1.[17] While the distributions are assumed to be normal, it should be noted that a false assumption of normality will not result in any prediction error of LSF so long as the mean is correctly estimated and the estimated standard deviation is appropriate for the lower tail of the true distribution.

The assumptions of normality of the yield distribution, price certainty, fixed input coefficients, and price-taking behavior by individual farmers are sufficient for normality of the distribution of net returns (π). These distributions are:

$$\pi(M_1) \sim N(800,400)$$
$$\pi(M_2) \sim N(910,480)$$
$$\pi(M_3) \sim N(1005,560)$$
$$\pi(T) \sim N(412,80)$$

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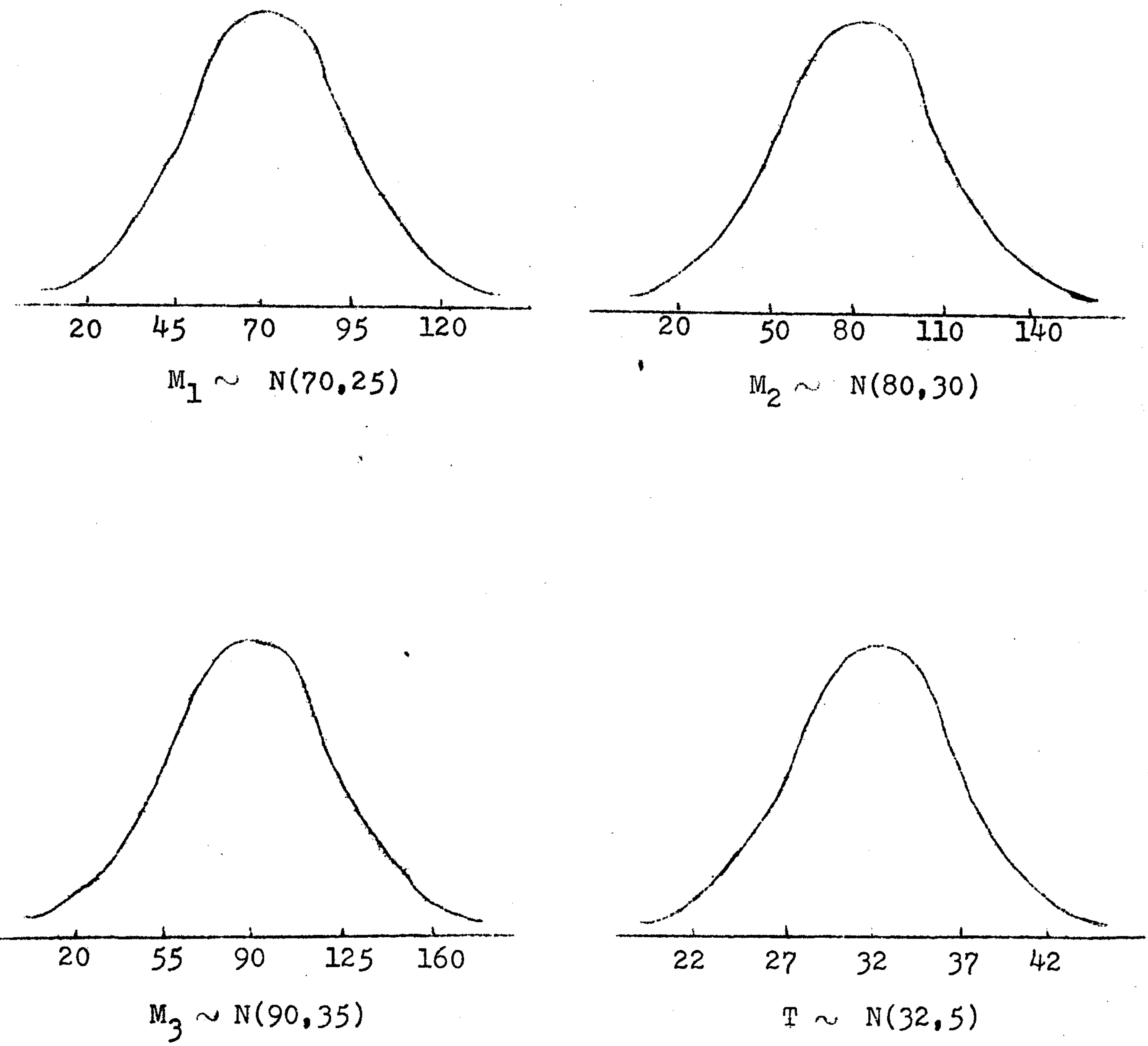
[16] Maximizing π_j will lead to the same decision so long as these rents are fixed costs. This is not necessarily always the case.

[17] The following assumptions were made in constructing Table 1: Family labor is subject to a constraint such that the opportunity costs of family labor are zero when the constraint is not binding and above the going agricultural wage when it is. Total costs of draft power do not exceed fixed costs, either because feed requirements do not depend on work performed or because feed is obtained at zero cost from otherwise idle fields.

Figure 1: Approximate Yield Distribtuion for Four Common Techniques in the Bicol Region



Written in this form the model is readily amenable to solution by hand or by computer according to the following steps:

1. Number the columns in the technique matrix from 1 to n. These numbers comprise the set, TUC.
2. Compute $F_i(\bar{d})$[18] for each $i \in TUC$ for the exogenously specified $\bar{d}$.[19]
3. List NOR based on the exogenously specified $\bar{\alpha}$.
4. Select the technique[20] from NOR for which μ_i is a maximum.
5. If NOR is empty, select the technique for which $F_i(\bar{d})$ is minimized (LSF_1) or $F_i^{-1}(\bar{\alpha})$ is maximized (LSF_2).

As an aside, note that the difficulty of developing solution algorithms for a programming problem with non-linear constraints is avoided by specifying F_i for all i.

LSF Nomographs

If a plotter is available, the computer can be used to compute the optimal techniques for different combinations of

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[18]At the University of Wisconsin where the computer work was done, subroutines are available to do this for a number of distributions including the standard normal.

[19]Discussion of the derivation of $\bar{d}$ and $\bar{\alpha}$ is included in a later section.

[20]It is theoretically possible that there is more than one technique that maximizes μ_i. This is unlikely to be a practical problem. If it is, the LSF models are easily expanded to include a third (or more) criterion as a "tie breaker."

$\bar{d}$ and $\bar{\alpha}$ coordinates. Contiguous regions representing $\bar{d}$ and $\bar{\alpha}$ combinations are then outlined. The resulting nomograph can be used for the following purposes:

1. To provide the solutions for a broad range of risk attitudes
2. To provide a sensitivity analysis for any particular solution well within the boundaries of the nomograph
3. To provide the basis of an estimate of the percentages of farmers in a given region using various techniques.

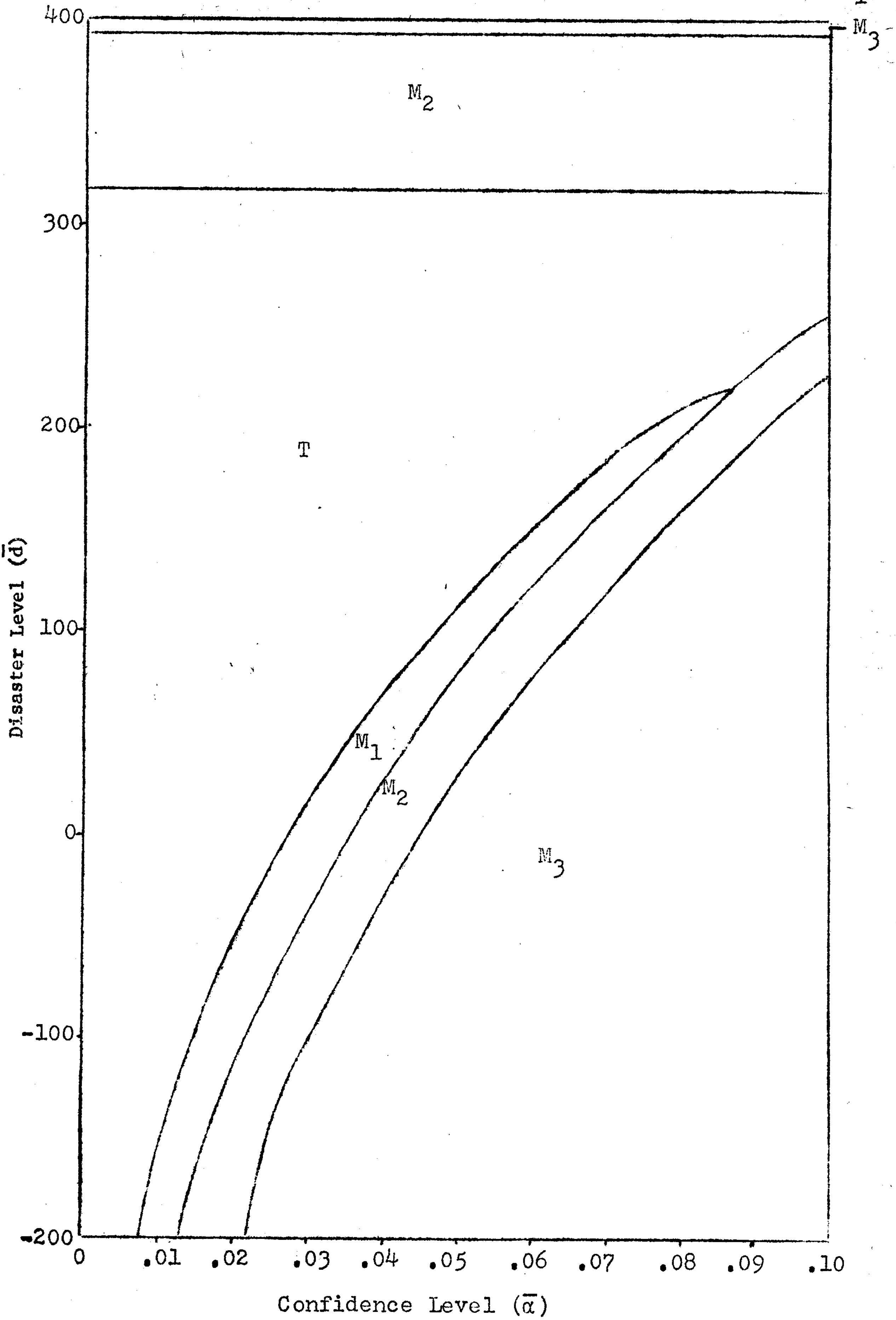
The two nomographs that follow give the solutions for the example in Table 1 under LSF_1 and LSF_2.

Exogenous Specification of $\bar{\alpha}$ and $\bar{d}$

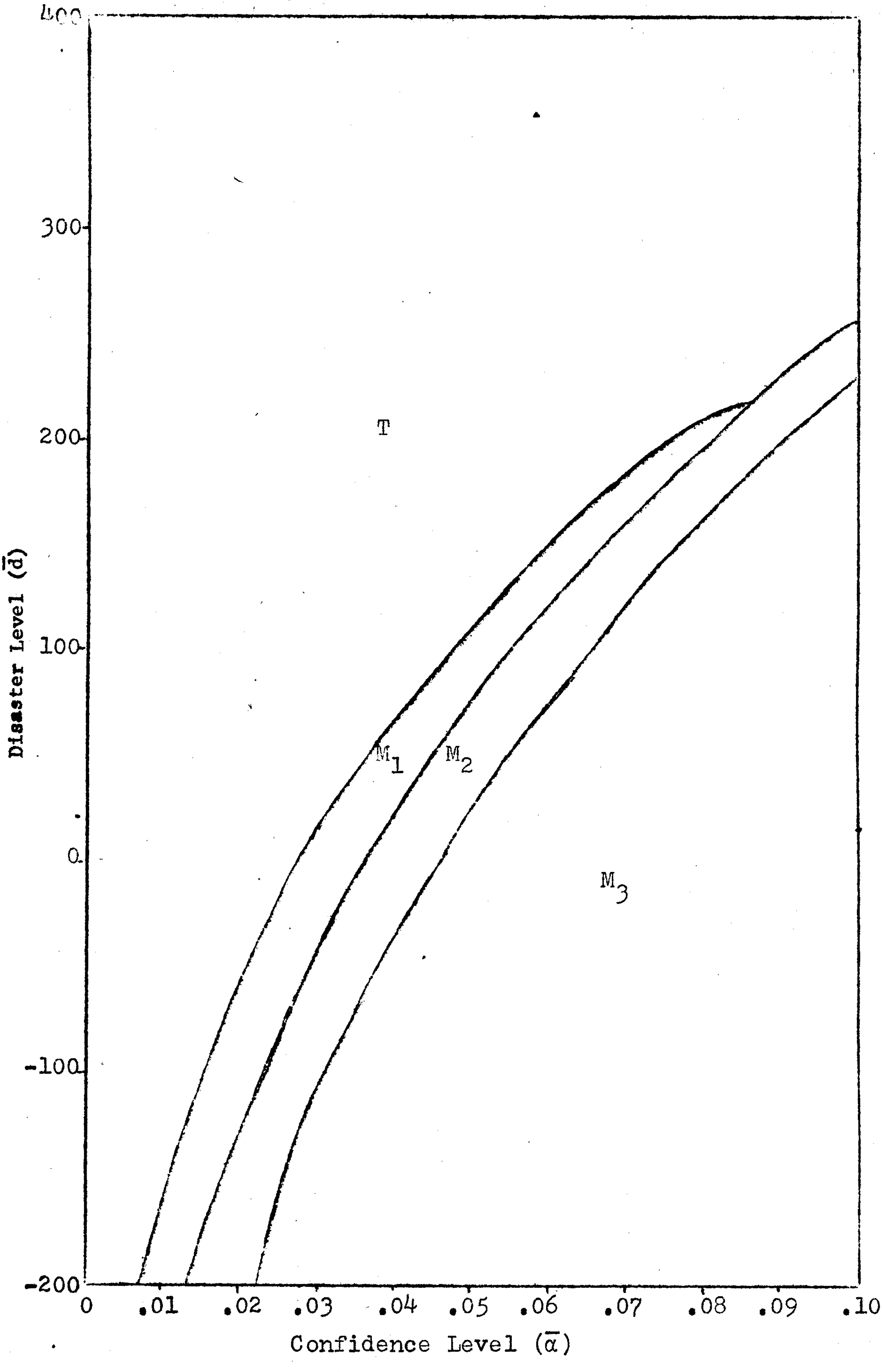
The choice of $\bar{\alpha}$, as the choice of the confidence level in statistical decision-making in general, should depend on consequences of error--in this case, the consequences of the actual returns falling below the disaster level. For the lowland rice areas of the Bicol Region, the penalty for failure is not certain death (starvation is extremely rare in rural Bicol), but instead the discomfort of adjusting to a lower standard of living and the loss of face associated with failing to provide the socially defined subsistence level.[21] For these stakes, the typical confidence level for the one-tailed test, .025, seems appropriate. Since the experiment

[21] For a discussion of biological vs. cultural subsistence levels, see Wharton [36,37].

Nomograph 1: Optimal Techniques for Rainfed Rice Land under LSF_1



Nomograph 2: Optimal Techniques for Rainfed Rice Land under LSF_2



is to be repeated several times (usually once a year for as long as the farm decision-maker is the family's principle supporter), .05 seems slightly large. (If the probability of failure is .05 each year for 30 years, the probability of failure at least once in 30 years is slightly over 3/4.) On the other hand, .01 seems to be a reasonable lower bound for the confidence level since the probability of failure at least once in 30 years is about 1/4 for a .01 probability of failing each year.[22] For the .025 confidence level, the probability of never failing in 30 years is about 1/2.[22]

The basis of $\bar{d}$ is assumed to be minimum consumption needs (MCN). Without specific cross-section data on levels-of-living in the study area, the best estimate of MCN is per capita carbohydrate consumption. For the Bicol region this is the equivalent of 2.2 cavans of milled rice,[23] or approximately 3.3 cavans of palay.[24] This implies roughly a 19-28 cavans per year[25] requirement for the typical range of family

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[22] Less than 1/4 where the .01 confidence level is not binding in all years.

[23] See Mears [22] Table IV-4. This is even higher than the average cereal consumption recommended by the Food and Nutrition Center of approximately 2.1 cavans.

[24] Farm yields, including those in this paper, are usually given in terms of palay, while consumption requirements are normally quoted in terms of milled rice.

[25] Accounting for the differences in the average age composition of different family sizes (see Atwater's index [4]).

size of five to ten members. In terms of the numeraire this is 300-400 pesos. Now define $\bar{d}$ as $\frac{MCN + UD - W}{H}$ where UD, urgent debts, represents the value of debts that must be paid-off in order that the farmer can retain his means of producing MCN, W is the resale value of the farm family's liquid assets, excluding the means of producing MCN, and H is the area of rice land in hectares. (While $\bar{d}$ is defined in terms of pesos, it is not a cash requirement in the usual sense. Indeed MCN represents the non-marketed portion of the harvest retained for home consumption.)

Since debts incurred in the current cropping season are subtracted in reporting net returns, MCN is a good upper limit for $\bar{d}$. Indeed for the majority of small farmers (those with 0-2 hectares), we would not be far off in ignoring W. For large landowners, $\bar{d}$ is typically a large negative number so that the chance constraint is never binding for profitable rice technologies.

Summarizing this *a priori* evidence, we can expect $\bar{d}$'s starting in excess of 400 (for large families with small plots of land) becoming most frequent around 170 (for a modal farm of 2.2 hectares and family size of 7 members)[26] and becoming less and less frequent thereafter as in Figure 2 below. The great bulk of farmers can thus be expected to have disaster levels of between 400 and -200, the range of $\bar{d}$ used in the

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[26] USAID, Rice in the Philippines, (March 1969), draft.

nomographs. Most of these fall between 315 and -15. For them the local variety combined with traditional techniques is the rational choice predicted by this model.

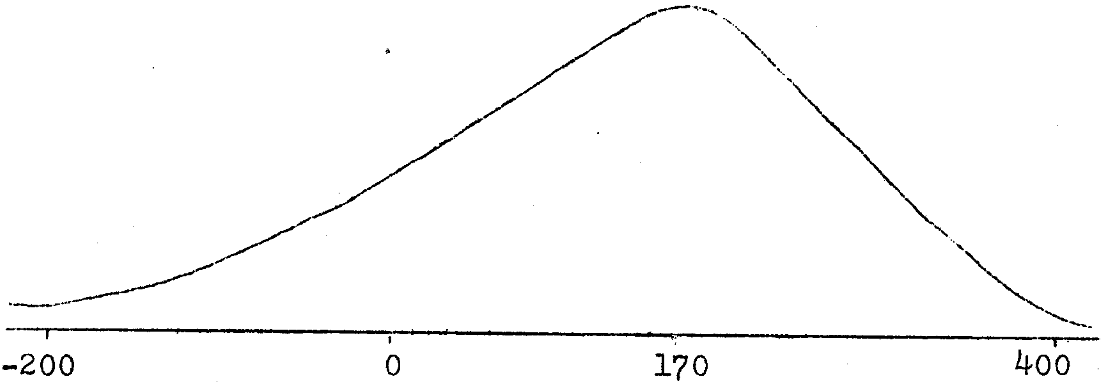

Figure 2: Hypothetical Frequency Distribution of Disaster Levels, Bicol Region

Irrigated Rice Farms

How does this picture contrast with the situation on irrigated farms? Table 2 shows the costs and returns for four hypothetical techniques for irrigated conditions in the Bicol Region.

The corresponding frequency distributions of net returns are:

$$\pi(T) \sim N(510, 128)$$

$$\pi(M_1) \sim N(960, 320)$$

$$\pi(M_2) \sim N(1055, 400)$$

$$\pi(M_3) \sim N(1135, 480)$$

Table 2: Technique Choices Available to the Average Operator of Irrigated Rice Land (per hectare): Bicol Region, Philippines*

	IR-5 Improved Techniques			Local Varieties Traditional Techniques
	M_1	M_2	M_3	T
ble Costs				
Fertilizer	90	120	150	40
Other Chemicals	30	50	80	0
Seed	25	25	25	20
Non-Family Labor	255	270	290	150
Interest	45	55	85	20
ns				
Average Yield	85	95	105	45
Average Gross Returns @ P16	1360	1520	1680	720
Variable Costs	400	465	545	210
Average Net Returns, π_j, (2-3)	960	1055	1135	510

d on cross-section data for the 1967 wet season obtained by the
l Development Planning Board and the IRRI Annual Reports, 1966-70.

The standard deviation are slightly lower under irrigated conditions. This reflects the assumptions that rainfall variation is the largest single cause of yield variation under non-irrigated conditions [2] and that there is a positive relationship between cash inputs and the standard deviation of net returns.

The nomographs under LSF_1 and LSF for these distributions are identical and are shown below as Nomograph 3.

We can conclude that the widespread reluctance of rice farmers of rainfed areas in the Philippines to adopt "modern" practices[27] is likely to be partly due to farmers unwillingness to bear the significantly large probabilities of disaster embodied in those techniques.

Reswitching of Risky Techniques

There is in general no monotonic relationship between risk, as measured by the probability of disaster, and variance. This can lead to a kind of reswitching of techniques[28] such as in Nomograph 1. As $\bar{d}$ increases at a given $\bar{\alpha}$, say .025, the optimal technique changes from M_3 to M_2, to M_1 to T, as the chance constraints for each technique become binding the optimum moves to a less risky, and in this case, a lower variance technique. But moving to even higher $\bar{d}$'s (above

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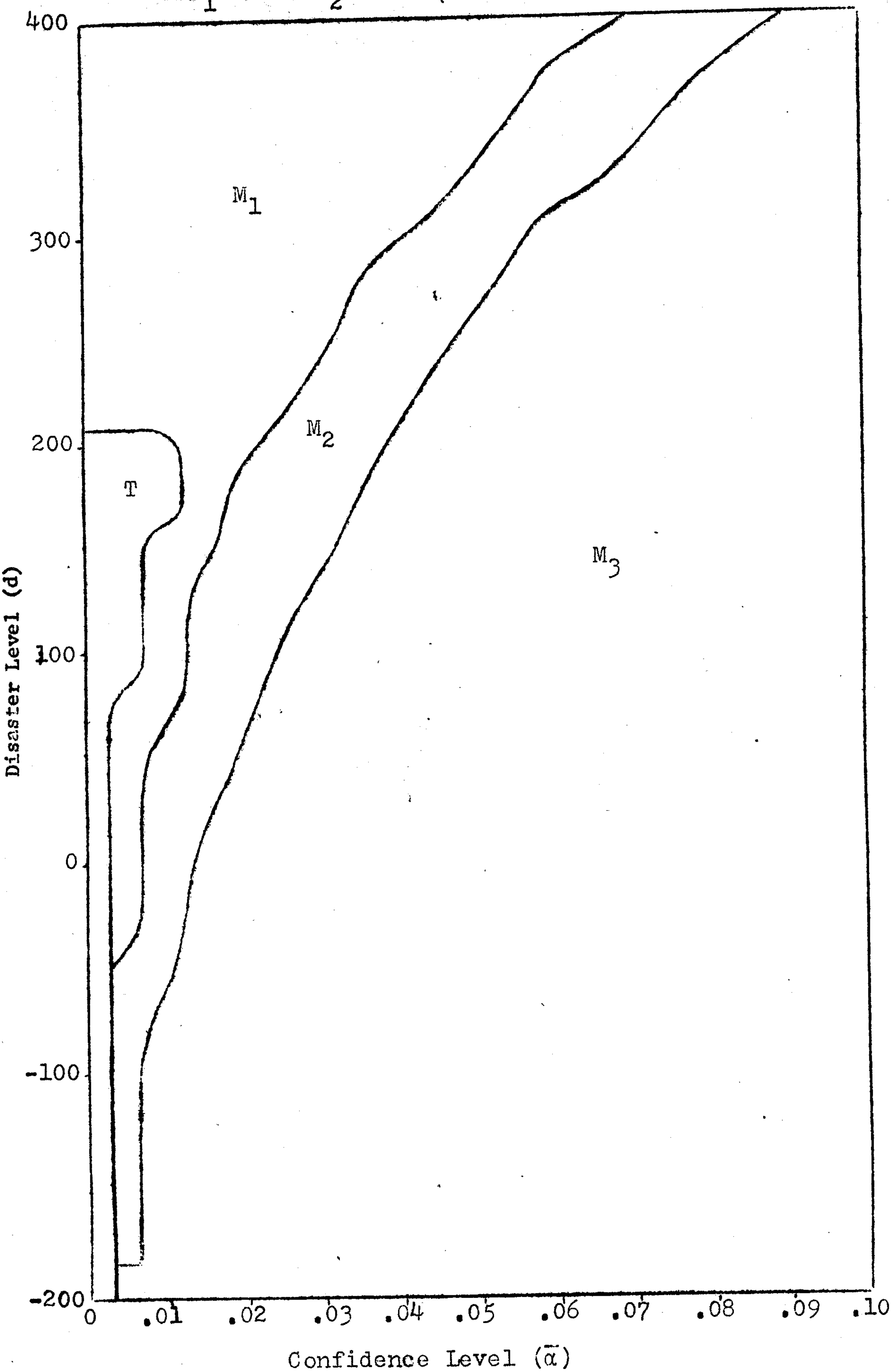
[27]See e.g., data from the Integrated Agricultural Survey conducted by BAEcon for the crop year 1970.

[28]A similar phenomenon to reswitching of risky techniques is discussed by Masson [21] in an expected-utility maximization framework and by Kunreuther [17].

Nomograph 3: Optimal Techniques for Irrigated Rice Land under LSF_1 and LSF_2



300), the higher variance techniques, M_2 and then M_3, reappear. Even though the variance is higher, the risk of disaster, at those $\bar{d}$'s, is lower.

No such reswitching can occur in LSF_2. This difference between the two models can be used as a basis for choosing one or the other as a better explanation (or prediction) of techniques chosen in cases where the two models give divergent results. For the Philippine case discussed above, if farmers with especially low wealth positions are found to be accepting high variance techniques more readily than farmers in the medium wealth range but not more readily than farmers in the high wealth range, the LSF_1 would seem to be preferable to LSF_2.

Another upshot of reswitching in LSF_1 is that while techniques can be uniquely ordered by variance, they cannot be ordered uniquely by risk of disaster where disaster levels differ for different farmers. This may help shed light on the relationship between cash inputs, especially fertilizer, per hectare and farm size which has puzzled agricultural economists [1,15,18,25,26,27,33] for years. One might expect farm size to be directly related to fertilizer inputs per hectare because of economies-of-scale in the transportation of fertilizer to the farm, low cost of credit based on better collateral, and lower aversion to risk given the higher level of wealth. In order for the risk aversion story to hold water, we need to establish that increasing the use of fertilizer increases the variance of net returns and that risk is monotonically increasing with variance. The first part is reasonable, but the second part is not due to the possibility of reswitching. This may provide part of the reason why fertilizer inputs per hectare and farm size do not seem to be consistently related empirically.[29]

Risk Premium and Certainty Equivalence

Another implication of the LSF models is that the traditional view of risk premium is inappropriate for two reasons. First the notion that there is some sure payment that can induce an individual to accept a fixed level of risk is based on the assumption of indifference curves on the mean-variance plane. But with the definition of risk embodied in the LSF models and in chance constrained programming, it is impossible to give a sure payment without reducing risk, provided that risk is positive without the payment. Second, even if we could identify a risk premium for an individual farmer and technique, the concept would not be useful because of reswitching. We cannot say that one technique must command a higher premium than another because the risk of a technique cannot be identified independently of the farmer who employs the technique. What is risky for one farmer may be the safest technique for another.

It is important to be clear about this matter of risk premium when it comes time to assess policy recommendations

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[29]See e.g., [1,18,31,33].

for increasing agricultural production. Agricultural economists are wont to observe that high-variance ventures require high expected rates-of-return to offset their riskiness. A rapid acceleration in the use of fertilizer in conjunction with the spread of HYV's has been taken as evidence of this view.[30] Fertilizer use has always been profitable, we are told, but only since the advent of HYV's are rates-of-return so high as to offset the risk of reswitching to new practices. But if our view of risk is appropriate, "offset" is the wrong word. The HYV's may have increased the expected return to using fertilizer to such an extent that it is no longer any riskier than using traditional varieties and no fertilizer.

In any case, the increase in expected return made the difference, so what's the quarrel? The quarrel arises in identifying the cheapest way to induce farmers to increase production. The traditional mean-variance approach leads us to the conclusion that expected value is the key, that the high variance of new techniques will be accepted if we shift the whole distribution of returns to the left by a sufficient amount. A guaranteed per unit price subsidy is ideal for this purpose. In the Safety-First view, however, price subsidies are a very inefficient way of decreasing risk. What is indicated is a package of policies designed to minimize the proba-

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[30]For an introduction to the Green Revolution that is resulting from the introduction of HYV's, see Cownie & Johnston [13] and C. R. Wharton, Jr. [38]. For a description of the conventional wisdom that the new technology in rice production requires a higher rate-of-return because it is more risky, see Dillon & Anderson [39]. The latter authors go on to criticize the conventional wisdom, but on different grounds than developed here.

bility of disaster at a low cost. Some candidates for inclusion in such a package are: crop insurance,[31] crop loans, emergency credit,[31] and price-floors.

Conclusions

Two models are recommended for explaining choice-of-technique when risk of disaster is a main concern. The method of solution and the LSF nomographs are illustrated for hypothetical cases involving the choice between modern and traditional techniques on rainfed and irrigated rice land. An interesting feature of LSF_1 is the possibility of reswitching from high variance to low variance and back to high variance techniques as the disaster level gets higher. The notion of risk premium is seen to be inappropriate under the LSF models. The policy implication is that raising the expected payoff via price supports is an inefficient way of reducing risk.

[31] Likely to be especially effective if adopting some minimum cultural practices (especially regarding fertilizer application) is made a prerequisite.

APPENDIX

I. LSF_1 and LSF_2 Interpreted by Mean-Variance Analysis for the Normal Case

It may be instructive for those of us who have spent many hours thinking of risk problems in terms of Markowitz-Tobin diagrams, to construct preference maps under LSF_1 and LSF_2 on mean-variance space. We proceed with this task after two notes of caution. First the exercise only makes sense under the assumption that the standardized distributions of returns from all techniques are identical. For the illustration here, this condition is satisfied by assuming the distributions for all techniques are normal. Second, we cannot draw indifference curves of the usual sort since the preference orderings cannot be represented by real-valued utility functions. The following algebra is useful in constructing the preference maps:

$$\Pr.(\pi_i < \bar{d}) \leq \bar{\alpha}$$

is written:

$$\Phi\left(\frac{\bar{d} - \mu_i}{\sigma_i}\right) \leq \bar{\alpha}$$

for the normal case or

$$\frac{\bar{d} - \mu_i}{\sigma_i} \leq \Phi^{-1}(\bar{\alpha})$$

which can be written as:

$$\mu_i \geq \bar{d} + \bar{k}\sigma_i$$

where

$$\bar{k} \equiv -\Phi^{-1}(\bar{\alpha})$$

In the preference maps shown below, for both LSF_1 and LSF_2, the triangular regions with horizontal lines satisfy the chance constraint, $\mu_i \geq \bar{d} + \bar{k}\sigma_i$. Points along these horizontal lines are not ranked by LSF_1 or LSF_2 in their present forms, i.e., the preference ordering under LSF_1 and LSF_2 are incomplete.[32] For LSF_1, where the chance constraint is not met, "lines of equal risk" are given by the equation,

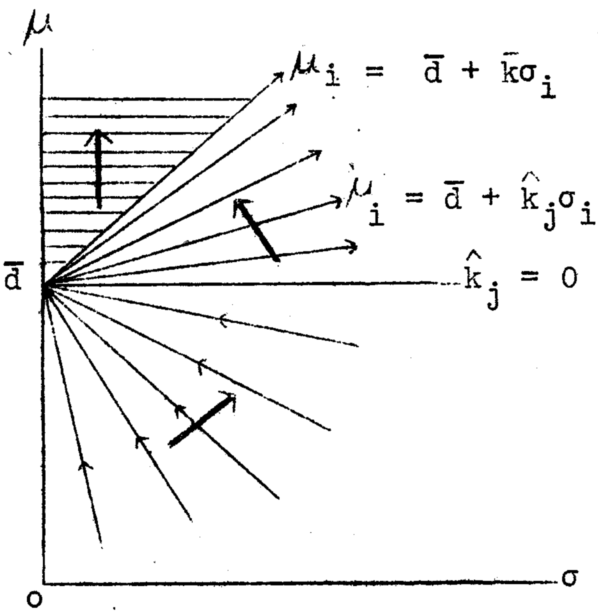
$$\phi\left(\frac{\bar{d} - \mu_i}{\sigma_i}\right) = \hat{\alpha}_j, \quad j=1\ldots n$$

or

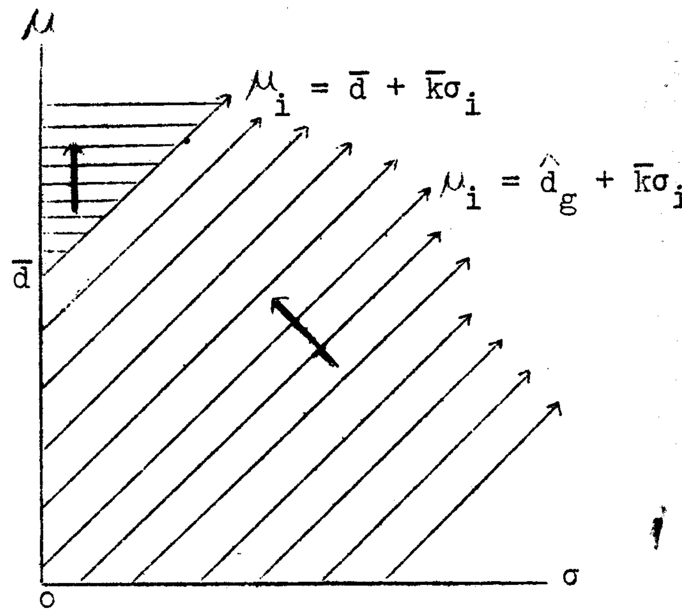
$$\mu_i = \bar{d} + \hat{k}_j\sigma_i$$

where $\hat{\alpha}_j$ is a fixed confidence level,

$$\hat{k}_j = -\phi^{-1}(\bar{\alpha}_j), \text{ and } 0 < \sigma_i < \infty$$



LSF_1



LSF_2

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[32]For the case under consideration here, using $-\sigma_i$ for the third dimensions of LSF_1 and LSF_2 makes the ordering complete, where $\sigma_i = E[\pi_i^2] + \mu_i^2$.

The small arrows on the lines of equal risk show the direction of risk for points on those lines.

For $\hat{\alpha}_j = .50$, $\hat{k}_j = 0$ so the corresponding line of equal probability of disaster is horizontal. This can be used to subdivide the area wherein the chance constraint is not fulfilled. In the upper of the two subdivisions, for two techniques with the same , the one with the lower σ is preferred. In the lower region, the opposite is the case--higher variance is desired. The large arrows show the direction of preference for the three regions.

The LSF_2 preference map has only two regions. The upper one is identical to that of LSF_1. In the lower region the lines of equal risk[33] are parallel, all with slope $\bar{k}$. Each is associated with a different "endogenous disaster level," $\hat{d}_g$, the higher the better.

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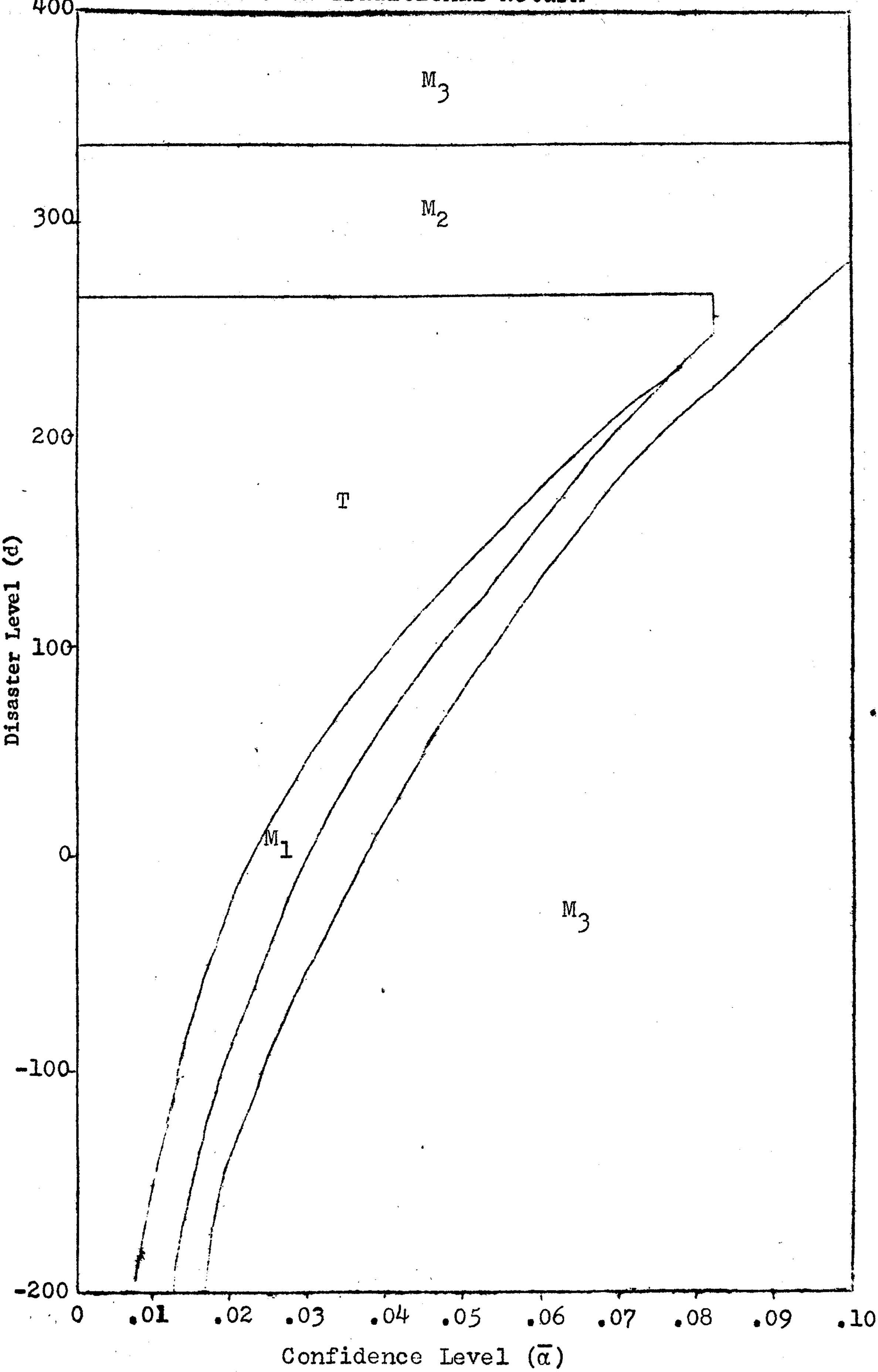
[33]While risk is the probability of disaster for both models, risk increases with $\hat{\alpha}_j$ for LSF_1, but for LSF_2, risk increases as $\hat{d}_g$ decreases.

II. Sensitivity to Estimated Variance

Perhaps the assumption that the standard deviation of technique T is five cavans per hectare is too low. How would nomograph 1 change if the estimate were raised? To answer this question, the standard deviation for T was doubled and the new probability distribution is assumed to be: $T \sim N(36,10)$ in yield terms and $\pi(T) \sim N(476,160)$ in terms of net returns. This distribution pushes the limits of credibility for both the upper and lower tails. It seems unlikely that the traditional variety would fare much more badly than the HYV's (16 cavans vs. 20-22 cavans) under the extremely adverse conditions associated with two standard deviations to the left of the mean; the traditional varieties have some inbred resistance to drought and other problems due to natural selection. On the other end of the distribution, N(36,10) implies a 2.5% chance of yields in excess of 56 cavans/ha. which seems too high for average, unfertilized soil.

The nomograph for $T \sim N(476,160)$ and the other three "modern" techniques from nomograph 1 was plotted under LSF_1 and is displayed below. The only change from nomograph 1 was in the region where $275 \leq \bar{d} < 325$ where T is displaced by M_2. For LSF_2 the sensitivity to the larger variance of T is even less. The nomograph for LSF_2 (not shown) is the same as the one shown here for $\bar{d} \geq 250$. For $\bar{d} < 250$, $\bar{\alpha} < .08$, T is predicted by LSF_2; and for $\bar{d} < 250$, $\bar{\alpha} > .08$, M_2 is predicted.

Nomograph 4: Optimal Techniques for Rainfed Rice Land for High Variance of Traditional Return



References

1. K. Bachman & R.P. Christenson, "The Economics of Farm Size," Agricultural Development and Economic Growth, H.M. Southworth & B.F. Johnston, eds., (New York: Cornell University Press, 1967) pp. 234-247.

2. J.P. Bhattacharjee, "Rapporteur's Report on Nature and Role of Risk and Uncertainty in Agriculture," The Indian Journal of Agricultural Economics, January-March 1964.

3. Board of Economic Enquiry, Punjab India; Family Budgets of 26 Cultivators in the Punjab, 1964-65, Economic Statistical Organization, Punjab Government, Publication 114, p. 4.

4. J. Boussard & M. Petit, "Representation of Farmers' Behavior under Uncertainty with a Focus-Loss Constraint," The Journal of Farm Economics, November 1967.

5. G.A. Carlson, "A Decision Theoretic Approach to Crop Disease Prediction and Control," The American Journal of Agricultural Economics, May 1970, pp. 216-223.

6. A. Charnes & W.W. Cooper, "Chance-Constrained Programming," Management Science, 1958, pp. 235-263.

7. R.H. Day, "Rational Choice and Economic Behavior," University of Wisconsin Social Systems Research Institute, Reprint Series No. 240, (reprinted from Theory and Decision I, (Dordrecht-Holland: D. Reidel Publishing Co., 1971), pp. 229-251).

7a. R.H. Day, D. Aigner, & K. Smith, "Safety Margins and Profit Maximization in the Theory of the Firm," The Journal of Political Economy, November-December, 1971.

8. G. Debreu, Theory of Value, (New York: John Wiley and Sons, 1959).

9. J. Dillon, "An Expository Review of Bernoullian Decision Theory," The Review of Marketing and Agricultural Economics, March 1971.

10. J. Encarnacion, Jr., "A Note on Lexicographical Preferences," Econometrica, January-April 1964.

11. ______________, "On Decisions under Uncertainty," The Economic Journal, June 1965.

12. A.N. Halter & G.W. Dean, Decisions under Uncertainty with Research Applications, (Ohio: South-Western Publishing Co., 1971).

13. B.F. Johnston & J. Cownie, "The Seed-Fertilizer Revolution and Labor Force Absorption," The American Economic Review, September 1969, pp. 569-582.

14. S. Kataoka, "A Stochastic Programming Model," Econometrica, January-April 1963, pp. 181-196.

15. R. Krishna, "Land Reform and Development in Southern Asia," W. Froelich, ed., Land Tenure, Industrialization, and Social Stability, (Milwaukee: Marquette University Press, 1961).

16. ______________, "Models of the Family Farm," C. Wharton, ed., Subsistence Agriculture and Economic Development, (Chicago: Aldine Publishing Co., 1969).

17. H. Kunreuther, "Risk Taking and Farmers' Crop Growing Decisions," Center Discussion Paper No. 115, Economic Growth Center, Yale University, June 1971.

18. S.H. Liao, S.C. Hsieh, & P.R. Sandoval, "Factors Affecting Productivity in Selected Areas of Philippine Rice Farms," The Philippine Agriculturist, October 1968, pp. 241-255.

19. ______________, "Factors Affecting Adoption of Improved Farm Practices on Rice Farms," The Philippine Agriculturist, October 1968, pp. 256-267.

20. H. Markowitz, "The Utility of Wealth," The Journal of Political Economy, April 1952, pp. 151-158.

21. R.T. Masson, "Rationale of Safety-First Criteria, Expected Utility Maximization, and a Risk Giffen Good," University of Chicago, (draft), August 1971.

22. L.A. Mears, "Rice and Corn Consumption Statistics," Institute of Economic Development and Research, University of the Philippines, Discussion Paper No. 71-3, February 1971.

23. J. Mellor, "The Use and Productivity of Farm Family Labor in Early Stages of Agricultural Development," The Journal of Farm Economics, August 1963, pp. 517-534.

24. C. Nakajima, "The Economic Behavior of Subsistence Farmers," C. Wharton, ed., Subsistence Agriculture and Economic Development, (Chicago: Aldine Publishing Co., 1969).

25. T. Ogura, Agricultural Development in Modern Japan, (Tokyo: Fiji Publishing Co., 1963).

26. H. Von Oppenfeld, et.al., "Results of a Study of Adoption of Better Practices in the Philippines," The Indian Journal of Agricultural Economics, 1962, pp. 173-175.

27. K.H. Parsons, "The Tenure of Farms, Motiviation, and Productivity," in U.S. Papers prepared for the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas, February 1963, 3:25-35, Washington, U.S. Government Printing Office, 1962.

28. D.H. Pyle and S.J. Turnovsky, "Safety-First and Expected Utility Maximization in Mean-Standard Deviation Portfolio Analysis," The Review of Economics and Statistics, February 1970, pp. 75-81.

29. J.A. Roumasset, "Risk and Choice of Technique for Peasant Agriculture: Safety First and Rice Production in the Philippines," University of Wisconsin Social Systems Research Institute, Economic Development and International Economics Paper #7118, August 1971.

30. ______________, "Lexicographic Safety First," University of the Philippines, Institute of Economic Development and Research, Discussion Paper No. 71-21, October 1971.

31. ______________, "Land Quality, Farm Size, Tenure and Productivity on Philippine Rice Farms," (typewritten).

32. A.D. Roy, "Safety First and the Holding of Assets," Econometrica, July 1952, pp. 431-448.

33. V.H. Ruttan, "Tenure and Productivity of Philippine Rice Producing Farms," The Philippine Economic Journal, First Semester 1966.

34. J. Tobin, "Comment on Borch and Feldstein," The Review of Economic Studies, January 1969, pp. 13-14.

35. S.J. Turnovsky, "Stochastic Demand and the Theory of the Firm," Discussion Paper No. 96, Department of Economics, University of Pennsylvania, 1968.

36. C. Wharton, Jr., "The Economic Meaning of Subsistence," The Malayan Economic Review, October 1963, pp. 46-58.

37. ______________, "Risk, Uncertainty and the Subsistence Farmer: Technological Innovation and Resistance to Change in the Context of Survival," Joint Session of the American Economic Association and Association for Comparative Economics, Chicago, December 1968.

38. ______________, "The Green Revolution: Cornucopia or Pandora's Box," Foreign Affairs, April 1969, pp. 464-476.

39. J. L. Dillon and J. R. Anderson, "Allocative Efficiency, Traditional Agriculture, and Risk," The American Journal of Agricultural Economics, February 1971, pp. 26-32.