Yield and Household Income Variability in India's Semi-Arid Tropics

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Yield and production stability figure explicitly in the mandates of several of the international agricultural research centers. Much of the investment in breeding, pathology, entomology, and physiology at the centers is aimed at developing higher and more stable-yielding, improved varietal technologies. These technologies have consequences for output, equity, and nutrition. Could they also improve the welfare of farm households by generating substantial reductions in the variability of household income and consumption? Such potential welfare improvements, associated with smoothing fluctuations in household income and consumption, are referred to as risk benefits in the stabilization literature of economics (Newbery and Stiglitz 1981). What is the potential for improved varietal technologies to generate readily visible risk benefits? Should economists assign additional positive benefits to varietal technologies that reduce yield or output variance over and above their consequences on mean yield or output, equity, and nutrition?

This chapter responds to those questions by examining the nexus between crop yield stability and household income variability for resource-poor farm households in India's semi-arid tropics (SAT). Typical of many households in this area, those in the present sample are very poor. Mean annual household income per person over the nine-year period of analysis averaged about U.S.$100.

Conceptualizing Risk Benefits

Risk benefits are defined as how much mean income farmers would be willing to sacrifice to obtain smoother income streams. How much farmers would be willing to pay depends on (a) their preferences for risk taking,

I thank M. Asokan and E. Jagadeesh for carrying out the crop yield simulations in this chapter. I am grateful to J. R. Witcombe, R. A. E. Mueller, and F. R. Bidinger for comments.

TABLE 25.1 Agroclimatic and technological features for three villages in India's semi-arid tropics from 1975/76 to 1983/84

Village (location, soils, annual mean rainfall)	Average Size of Operational Holding (ha)	Irrigated Area as Percent of Gross Cropped Area	Common Crops	Improved Technologies Adopted
Aurepalle (Mahbubnagar district, Alfisols, 620 mm)	4.3	21.4	Irrigated paddy, castor, sorghum, pearl millet	HYV paddy, HYV castor, fertilizer on irrigated land
Shirapur (Sholapur district, deep Vertisols, 660 mm)	4.8	9.4	Sorghum	Fertilizer on irrigated land
Kanzara (Akola district, medium deep Vertisol, 930 mm)	5.0	7.1	Cotton, sorghum, mung bean, pigeon pea	Hybrid sorghum, fertilizer, insecticide and mechanical threshing

(b) their perceptions of how much alternative technological options would buy of lessened household income variability, and (c) their ability to adjust to income risk through transactions in credit and asset markets and changes in storage. Higher risk aversion, a perception that varietal stability could significantly reduce household income variability, and an inability to adjust cost-effectively to risk would increase the demand for more stable yielding cultivars.

From microeconomics literature, one simple way to analyze variability consequences is to compare the coefficient of variation (cv) of household income with and without a stabilization policy (Newbery and Stiglitz 1981). Large risk benefits are obtained when the simulated household income cv with the policy is substantially less than the cv without the policy. Before this mean-variance framework is used to quantify the value that farm households might place on yield stability, the data base is described.

Villages, Data, and Weather

The study is based on longitudinal data from three villages which are representative of three broad soil, climatic, and cropping regions of India's semi-arid tropics (table 25.1). Production risk is significantly greater in drought-prone Aurepalle and Shirapur than in rainfall-assured Kanzara.

The institutional environment for risk adjustment also differs considerably among the villages. Shirapur and Kanzara belong to Maharashtra state which has invested heavily in public work projects, most notably the Employment Guarantee Scheme (EGS). In Aurepalle, in the Mahbubnagar district of Andhra Pradesh, households do not have access to a government employer of last resort, and the local labor market is less buoyant than in the Maharashtra villages.

In 1975 a panel was drawn from a random stratified sample of small-, medium-, and large-sized farming and landless labor households in each village. Forty households were selected in each village, 10 from each stratum (Jodha, Asokan, and Ryan 1977). Household data on plot cultivation, transactions, and labor market participation, wages, and employment were collected by a resident investigator at three- to four-week intervals (Singh, Jodha, and Binswanger 1986). Information on eight other schedules was updated annually.

Household income is estimated for nine cropping years from 1975/76 to 1983/84. Concepts and procedures used to estimate income are given by Singh and Asokan (1981). Income conceptually refers to net household income which represents returns from family labor, management, capital, and land. Revenues and expenses from both farm and nonfarm activities were included in estimating net household income. Dowry and other large transactions pertaining to life cycle events were not included.

TABLE 25.2 Descriptive information on the common crops sown in the study villages in India from 1975/76 to 1983/84

					Mean Coefficient of Variation[b]		
Crop	Village	Number of Farm Households[a]	Mean Years Cropped	Percent of Gross Cropped Area	Household Income	Yield	Price
Irrigated paddy	Aurepalle	9	8.1	12	0.47	0.31	0.07
Castor	Aurepalle	23	7.6	34	0.45	0.68	0.22
Sorghum	Aurepalle	21	7.3	18	0.41	0.66	0.12
Sorghum	Shirapur	21	8.3	58	0.34	0.69	0.17
Cotton	Kanzara	26	8.2	51	0.33	0.44	0.15
Hybrid sorghum	Kanzara	18	7.2	8	0.34	0.66	0.13

[a]Those that planted the crop for at least five years from 1975/76 to 1983/84.
[b]Simple means of the cvs. For income and yields the cvs are at the household level but for price they are based on village average harvest prices.

The analysis relates to the "continuous" cultivator households who remained in the panel over the whole period. For those 81 households, information on fluctuations in income was summarized by the cv of annual net household income. A cv was estimated for each household based on nine years of income data deflated by a village-specific consumer price index (Walker et al. 1983).

The Common Crops and Household Income Variability

To measure risk benefits generated by the reduced yield variability associated with improved, more stable-yielding technologies, the most common crops grown in each village were the subjects for analysis. Those crops include irrigated paddy in Aurepalle and five dryland crops—sorghum and castor in Aurepalle, post-rainy-season sorghum in Shirapur, and cotton and hybrid sorghum in Kanzara. Included in the analysis were those cultivators who planted the crop in at least five of the nine years. With the exception of hybrid sorghum in Kanzara, many of the sample farm households planted the crop each year, but in varying areas.

Descriptive information on the households cultivating the common crops is presented in table 25.2. Many of the so-called common crops are not really so common, reflecting a diversified cropping pattern typical of dryland agriculture in India's semi-arid tropics. The most common village cropping system is post-rainy-season sorghum in Shirapur, which accounts for about 60 percent of gross cropped area in the village.

The mean household income cvs range between 0.33 and 0.47 and reinforce the popular image of production uncertainty in dryland agriculture in India's semi-arid tropics. Still, only 10 of the 81 continuous cultivar households had cvs exceeding 0.50. It was not surprising to note that household income was more variable in Aurepalle than in Shirapur, where off-farm employment opportunities are more ample, or in Kanzara, where the production environment is not as harsh. Lastly, yield variability on average was an order of magnitude three to five times greater than price variability. Prices were remarkably stable over the period of analysis.

Empirically Determined Risk Benefits

To assess the size of the risk benefits potentially offered by reductions in crop yield variability, the most extreme possible scenario, perfect crop yield stabilization, was examined. Under that scenario, each household received its mean yield level each year that the designated common crop was planted during the nine-year period of analysis. The cv from the simulated household income based on perfect crop yield stabilization was then compared with the cv from actual household income, the latter already

TABLE 25.3 Simulated risk benefits from perfect crop yield stabilization

Crop	Village	Number of Farms	Mean cv of Household Income	Mean Percentage Reduction in the cv of Household Income	Mean of Individually Computed Risk Premiums as Percentage of Mean Income
Irrigated paddy	Aurepalle	9	0.466	15.4	2.9
Castor	Aurepalle	23	0.448	4.4	1.2
Sorghum	Aurepalle	21	0.344	1.0	0.2
Sorghum	Shirapur	21	0.340	−3.9	−0.2
Cotton	Kanzara	26	0.330	0.8	0.2
Hybrid sorghum	Kanzara	18	0.344	0.6	0.3

embodying the effects of the household's own attempts to manage risks.

The assessment is based on the assumption that households do not materially change their behavior in response to perfect crop yield stabilization. That assumption would not hold for some crops and locations. The assumption is strongest for Kanzara where opportunities for diversification are much greater than in Shirapur and Aurepalle. In Kanzara, yields in and revenues from hybrid sorghum production are considerably more variable than those in competing cotton intercropping systems. If yield variability were reduced in hybrid sorghum, farmers would shift some of their cotton area into hybrid sorghum production (Walker and Subba Rao 1982). Nonetheless, because the demand for hybrid sorghum is very price inelastic, those transfer benefits would be short-lived and ultimately would go to consumers.

If perfect yield stability significantly decreases fluctuations in labor demand, risk benefits will be underestimated. Similarly, to the extent that improved yield stability results in increased area planted to the stabilized crop, the results presented here could understate longer term risk benefits. Nonetheless, perfect yield stabilization is an extreme assumption, which is not remotely feasible in dryland agriculture in India's semi-arid tropics. Such an extreme scenario should more than compensate for the partial nature of the analysis to be biased toward underestimated risk benefits.

Risk benefits from perfect crop yield stabilization are measured in two ways in table 25.3, namely, (a) mean percent reduction in the cv of household income and (b) what a household would be willing to sacrifice in mean income to gain a reduction in income variability attributed to perfect single-crop yield stabilization. This latter risk benefit is expressed as a proportional risk premium which is calculated by multiplying the difference between the squared cvs with and without perfect yield stabilization by one-half of the relative risk aversion coefficient (Newbery and Stiglitz 1981, p. 93, equation (6.5), Kanbur 1984). The value of the latter is often assumed to be unity (Newbery and Stiglitz 1981). Newbery and Stiglitz partially justified this assumption with experimental evidence from study villages of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (Binswanger 1981).

To illustrate the computations summarized in table 25.3, consider a household with an income cv of 0.5. For a reduction in variability of 60 percent (to cv = 0.2), the proportional risk premium is calculated as $(0.5)(1)(0.5^2 - 0.2^2)(100) = 10.5$ percent.

The results in table 25.3 may be rather disheartening to plant breeders pursuing stability. For the six common village crops, the risk benefits from perfect single-crop yield stabilization range from modest to negligible. Ironically, risk benefits are highest in irrigated paddy, the crop with the lowest mean cv of yield. Removing variability from the yield of only one crop is simply not an effective way to reduce income variability for the vast majority of farm households. For the dryland crops, the largest risk benefits would accrue from stabilizing the yields of castor in Aurepalle; however, perfect yield stabilization would only reduce household income variability by about 5 percent. Such a modest change would be equivalent to less than 2 percent of mean household income.

The results in table 25.3 are based on a mean variance approach. Income variability is measured from the continuous perspective of cvs. Would the outcome have been more favorable to perfect crop stabilization if a framework was used in which risk benefits were assessed in discontinuous terms, such as disaster levels of income and minimum probabilities? While there is an almost limitless number of threshold levels of income and probabilities from which to choose, one intuitively appealing threshold concept is the income level below which the household is compelled to make a distress sale of land. That disaster level does not apply to the study villages because, over the past 40 years, distress sales of land have been rare. Moreover, land sales were not bunched in adverse rainfall years, suggesting that household risk adjustment was at least minimally effective in dealing with covariate weather risk (Cain 1981). Even during the massive 1971-73 drought in western Maharashtra, few households in Shirapur parted with their land.

Rather than ignore the question of threshold changes in welfare, the probability that a household would suffer a shortfall in income (in at least one of nine years) below 50 percent of its median income was examined. Many cultivators, particularly households in Aurepalle, fell into this shortfall category. Could perfect yield stabilization have prevented them from suffering such a steep decline in income? In fact, it would not have made much of a difference. Without perfect single-crop stabilization, 45 of the 118 crop-household combinations belonged to the shortfall set; with it, 38 households comprised the shortfall set. This result is consistent with the observation that yield risk was only one of several factors contributing to such shortfalls in household income (Walker et al. 1983).

Another way to view single-crop yield stabilization is to use perfect all-crop income stabilization as a point of reference. Stabilizing income from all crops at its mean level for each household leads to appreciable reductions in income cvs. Mean cvs for farm households fall by from 27 percent for cotton growers in Kanzara to about 60 percent for paddy producers in Aurepalle. Stabilizing the yield of a dominant crop exploits at most only about 25 percent of the potential risk benefits from perfect crop income stabilization.

Area Variability

Perfect single-crop yield stabilization does not much enhance risk benefits for several reasons, including three in particular: (a) Most households rely on multiple sources of income and contain family members who participate in the local village labor market. (b) Diversified cropping patterns are the norm in dryland agriculture in India's SAT, and for many households revenue from a single crop did not contribute an overwhelming share to crop income. (c) Area variability in dryland agriculture severely erodes the effectiveness of policies or technologies that work through yield to reduce variability in household income and consumption. The first two explanations are self-evident, but the third warrants further discussion.

A large share of area variability in dryland agriculture stems from decisions taken by farmers to cope with agroclimatic risk. In the granitic rock, drought-prone production regions of the Deccan, where irrigated area depends on surface runoff into large ponds and on groundwater supplied from dug wells, planned area for a crop often deviates markedly from actual area sown. In Dokur, a study village in Mahbubnagar district, the gross irrigated area fell from about 500 hectares in a normal year to about 200 hectares in 1985/86, a year of abnormally low rainfall. In a normal year, about 60 percent of gross cropped area is irrigated in Dokur. Both castor planted in July in Aurepalle and post-rainy-season sorghum planted in late September in Shirapur are sown when farmers have some information on soil moisture at the start of the cropping year. Both crops were subject to sharp fluctuations in area planted during the nine-year period of analysis. When the monsoon is late in Aurepalle, the potential for shootfly to inflict yield losses on sorghum is greater. Farmers respond by substituting castor for sorghum. As a consequence of early season drought in 1977/78, the average area sown to local sorghum was halved while mean castor area increased by about 40 percent. Similarly, farmers in Shirapur react to low rainfall years by planting less area to post-rainy-season sorghum which is grown on residual soil moisture.

In table 25.2, yields are shown to be appreciably more variable than prices from 1975/76 to 1983/84. When the cv of area for each household was calculated as it was for yields and prices in table 25.2, it was found that mean area variability exceeded mean yield variability for each of the six common crops. Unless some means can be found to mitigate the role of area variability in conditioning fluctuations in household income, policies or technological changes that focus on reducing fluctuations in yield will have only a limited effect on household income variability.

Speculating on Risk Benefits in Africa's Semi-Arid Tropics

Risk benefits from less variably yielding varietal technologies may be larger in Africa's semi-arid tropics because resource-poor households may rely more heavily on crop income than do similar households in India's semi-arid tropics. Moreover, those households may have fewer effective means by which to adjust current income to consumption requirements. In the more land-abundant African societies, local rural labor markets are not nearly as well developed as in India. Land abundance also implies that it would be administratively infeasible to establish a flexible public works program such as the Maharashtra Employment Guarantee Scheme that caters to local village employment.

India, being such a large country, also offers much greater scope for risk pooling than the smaller African nation states. Largeness buffers the labor market from locally covariate risk. Additionally, institutional stabilization alternatives, such as crop or rainfall insurance, are more actuarially attractive in India because an insurer has greater opportunities to diffuse covariate risk within national boundaries. In India, risks are also to some extent shared between the central and the state governments, both of which have a strong voice in agricultural stabilization policy.

The size of risk benefits is ultimately an empirical question. Household panel data are a rare commodity anywhere in the world, but they are particularly sparse in Africa. Hopefully, data bases from village studies started by ICRISAT in Burkina Faso in 1980 and in Niger in 1982 can be used in comparative analyses to address the issue of household risk benefits in West Africa's semi-arid tropics.

Conclusions

Apparently little economic value should be attached to the supposed risk-reducing attributes of improved varietal technologies for resource-poor households in India's semi-arid tropics. Such technologies should be evaluated primarily with regard to their impact on equity, nutrition, and mean yield or output levels. Risk benefits arising from presumed reductions in variability in household income are likely to be too small in practice to be measurable. On average, it seems that households in the study sample would be unwilling to part with more than 3 percent of their income to obtain such benefits.

The results from the simple simulations do not support the popular belief that crop yield stability should be prized highly for small farm households in India's semi-arid tropics. Increased yield variability is unlikely to manifest itself in markedly heightened household income variability. Policies such as crop insurance, which work through yields to smooth fluctuations in household income, offer little protection from income variability (Walker, Singh, and Asokan 1986). These concluding remarks may not, however, apply to Africa's semi-arid tropics where more research on household risk benefits is needed.

most part, the coefficients are significantly different from zero at the 5 percent confidence level. Greater adoption of hybrids has increased interregional yield covariances in both sorghum and pearl millet production. More covariate rainfall events have also led to significantly more covariate interregional yields. For sorghum, change in irrigated area behaves as expected; however, irrigation leads to reduced interregional pearl millet yield covariances. This puzzling result could stem from the fact that irrigated pearl millet often entails only one or two applications of water and is largely cultivated where water supply is most uncertain. A closer look at changes in irrigated area by source may shed some light on this result.

Conclusions

Having shown that adoption of HYVs is positively correlated with, if not partially responsible for, increased sorghum and millet production variability, it would be facile but unwarranted to conclude that scientists in the sorghum and pearl millet All India coordinated crop improvement programs should have released hybrids and varieties with a broader genetic background and should have pursued a more regional or location specific release strategy to mitigate the adverse effect of increasing interregional yield covariance and rising production variability. Even with hindsight, it is impossible to say whether the benefits from following a more regional release policy and emphasizing selection and breeding from genetically more diverse populations would compensate for the productivity gains forgone from pursuing a more single-minded, national yield improvement strategy. Moreover, a judicious mix of international trade and storage policies can cost-effectively offset most, if not all, of the variability costs of increasing yield covariance. These issues are addressed more fully in part III of this book.