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VARIABILITY IN GRAIN YIELDS

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Many countries have achieved impressive rates of growth in national food-grain production in recent years. Much of this growth can be attributed to new technologies, especially improved varieties, and the increased use of irrigation and fertilizers. As agricultural output has grown, however, so often has variability in yields from year to year. This presents potential problems and concerns that need to be addressed by the agricultural research and policy-making community. Prominent among

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these concerns are perceptions of increased risk, which may make new technologies less attractive to farmers and hence slow agricultural development, and increased instability in national and world food supplies, which may act to destabilize domestic prices, national income, and the food consumption of the poor, especially in poor agrarian countries.

Variability in Grain Yields: Implications for Agricultural Research and Policy in Developing Countries, edited by Jock R. Anderson and Peter B. R. Hazell (Baltimore, Md.: Johns Hopkins University Press for the International Food Policy Research Institute, 1989), reviews available evidence on patterns of variability in cereal production and how these patterns have changed in recent years. The biological, climatic, and economic factors underlying yield variability and its changes are discussed, and implications are sought for both agricultural research and policy.

At the global level, production variability around the growth trend increased between the 1960s and 1970s in both absolute and relative terms. The associated probability of a major shortfall below the trend in world cereal production has also increased. These changes have presented challenges for farmers, consumers, and policymakers, but they are not statistically significant. This suggests that the past decade has provided an example of unfortunate chance rather than a forecast that fundamental structural changes in production will cause equal or increasing instability at the global level in future years. Aggregate statistical tests, however, do not capture the effects of individual changes that are known to have taken place (for example, the "green revolution" and increased irrigation). Many individual factors are at work, some of which have a stabilizing effect at the aggregate level, while others are destabilizing. The degree of future variability will depend on the particular configuration of further changes in cereal production, the combined effects of these changes, and the outcome of the many relevant random variables. The need to understand the structural factors underlying production variability is therefore apparent.

PATTERNS OF YIELD VARIABILITY

Statistical analysis shows that baseline production variability is due primarily to yield variability. The increase in the variability of world cereal production since the 1960s (contrasting the periods before and after 1971) is also predominantly due to increases in year-to-year variations in yields of individual cereals along with increasingly correlated patterns of yield variation among different cereals. This book focuses on yield variability because it is the major variable of interest in comprehending production variability. It is also a simplifying focus, enabling abstraction from the complexities of variability of areas sown or harvested, which encompass a much wider range of economic and policy considerations.

Baseline yield variability is high in many countries, especially in Africa, the Middle East, and Australia. The level of variability is clearly related to climatic factors; it is greatest in semiarid areas and lowest in humid areas. Southeast Asia has especially low relative variability, but North and South America and Europe are also relatively stable. The high variability areas also tend to have low average yields and have done least well in increasing yields in recent times.

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There have been considerable differences among the changes in variability of individual cereal yields at the global level. Relative variability of yield has decreased for rice and millet, changed little for wheat, and increased

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by such means as improved cultural practices and plant breeding. Reducing variability will be worthwhile only if it can be achieved more economically than can ways of coping with it.

In principle, crop insurance is one attractive way of helping farmers cope with yield risks, especially where the risk of catastrophic losses is high. Unfortunately, past experience with crop insurance is not encouraging, and the costs of publicly provided insurance have usually far exceeded the benefits. Nor should the efficiency with which farmers and traditional village institutions cope with risks be neglected. Crop insurance might sometimes simply provide a more costly substitute for existing private risk-sharing arrangements. Improvement of financial institutions might be a viable approach, particularly if these involve an expansion of medium-term consumer credit so that farmers can more readily borrow money in bad years and pay it back in good years.

Effective marketing systems for farm inputs and outputs must be seen as a necessary condition for improving the opportunities of rainfed farmers to manage their risks. Just as for financial institutions, marketing systems by their very nature are generally expected to work best with only carefully chosen and restrained interventions.

At the national level, increased variability in prices and food consumption can be contained through buffer stock schemes. However, in most cases, it is more cost-effective for governments to use world markets to stabilize domestic consumption, sometimes using the International Monetary Fund's food facility as a source of funding for food imports when appropriate. Interventions can also be targeted on specific socioeconomic groups, such as food subsidies for the poor, or on relief employment and food-for-work schemes.

In terms of reducing risks on farms, the major disadvantage of commodity price stabilization is that farmers are not so much concerned with price variability as with income variability. Stabilizing prices may even lead to increased income variability. This possibility is likely if price and yield are negatively correlated, or if farmers grow several crops whose returns, though individually unstable, are collectively relatively stable. There may also be situations where price risk is not particularly important. Further, government intervention to reduce price risk will be more difficult to sustain the larger the country's share of the commodity in the world market, the more important the commodity in the economy, the longer the period of production, and the more porous the national border.

The quality of decisionmaking in highly variable and risky environments depends crucially on the information available to decisionmakers. In the world food systems that are influenced by variable yields of cereals, decisionmakers are involved at many levels ranging from individual farms through local marketing agents and food security administrators, regional and national authorities concerned with input and output delivery systems, and food policy authorities to international counterpart agents. Better information is required at all these levels.

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The variability of natural and economic environments explains much of existing public investment in information-gathering and -processing systems. If factors such as weather, production, and prices were not variable, and thus were easily known by all concerned, there would be little need for national meteorological services, national statistical services, and interpretative research agencies (for example, economic forecasting agencies). As well as describing variable environments in perceptive ways that add to the stock of knowledge, these institutions can further assist decisionmakers by attempting to forecast such uncertainties as droughts, frosts, pest and disease attacks, crop marketing volumes, trade volumes, flows of food aid, and prices. The difficulty of such work and its inherent inaccuracy do not mean that it may not be extremely valuable.

An important policy issue is the extent to which existing investment, both public and private, in the provision of information is at about the right level. The public-good nature of much of the relevant information ensures that private investment will be much less than is socially optimal. There is, however, a dearth of research on how adequate the public initiatives have been. But it seems clear that most developing countries are still severely underinvesting.

Attempts to draw definitive conclusions about the cost-effectiveness of different approaches in reducing or coping with yield variability are doomed to flounder until more quantitative information is available about the costs and benefits of each approach. For example, plant breeders could, by giving more emphasis to stability, reduce yield variability, but only by sacrificing perhaps sizable increases in average yields. Such sacrifices could prove costly to society, and a full social benefit-cost analysis might show alternative approaches to be better. It seems likely that more careful management of inputs and improved agronomic practices may be a relatively more cost-effective way of reducing yield variability at the farm level than plant breeding.

Perhaps relatively more is known about the costs and benefits of public policies for coping with variability, especially crop insurance, price stabilization, food subsidies, and food-for-work programs. Experience shows that these can all be very expensive unless carefully targeted on the households most adversely affected by production variability. It is also well established that, for most countries, international trade is an efficient way of reducing variability in prices and food supplies at the national level. This volume is intended to stimulate the kind of carefully focused research on yield variability that is needed to provide better recommendations to agricultural policymakers.

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CONSEQUENCES OF INCREASED YIELD VARIABILITY

Increased yield risks associated with improved varieties or new technologies may hinder their widespread adoption by farmers, thereby limiting growth in national food supplies. There is ample empirical evidence to show that most farmers act in risk-averse ways when making resource-allocation decisions that affect their income. However, studies of the relationship between yield risks and adoption of specific varieties or technologies show mixed results, probably because of the different types of technologies and farming systems studied (for example, irrigated versus rainfed agriculture). Since it is the stability of income (and family consumption) that concerns farmers most, increased yield risks should be a problem only if they lead to greater instability in income.

Yield risks are only some of many risks that affect a farmer's income, and some risks may act to offset each other. Within a crop, higher yield risks may be partly offset by negatively correlated fluctuations in prices, and the return from the crop may be much more stable than the variability of prices and yields considered separately would suggest. When more than one crop is grown, there is also scope for low or even negative correlations between the returns of the different crops, with a resultant stabilizing effect on aggregate income. Surprising efficiencies in reducing income risks have been achieved by small-scale farmers—for example, in dryland India—through a variety of cultural practices (such as intercropping, spatial diversification, and staggered planting dates), off-farm employment, use of credit, and participation in land-leasing arrangements that effectively share some of the yield risks with landlords.

High production years for major cereals should be good for poor consumers. They should benefit from more plentiful food supplies, from lower prices, and from increased agricultural employment. The opposite might be expected in low production years. However, since consumers typically purchase a number of different food crops, shortages or high prices for one crop may be offset simply by substituting other foods whose supplies are more plentiful or whose prices are lower.

Aggregate production variability does not necessarily translate into national food-security problems. Many governments do seem to take effective action through storage and trade policies to dampen fluctuations in domestic consumption, and consumers substitute between foods in response to their relative scarcities. However, in several smaller semiarid countries of Africa, extended droughts, in conjunction with inadequate famine-policy response, can have devastating effects on food consumption. Even in countries where aggregate food consumption is relatively stable, the consumption of some of the poorer households can still be at risk, particularly when their incomes are tied to agricultural production. Food-security problems therefore continue in many developing countries, even where the variability of aggregate production has not increased.

IMPLICATIONS FOR AGRICULTURAL RESEARCH

Plant breeders have long recognized the importance of selecting "stable" varieties. They have achieved—especially for wheat and rice—significant gains in adaptability, hardiness to extreme conditions, and reduced vulnerability to pests and diseases. But the gains in stability components may be compromised by selection for responsiveness.

Recent and contemporary plant breeding does not seem to explicitly address the yield correlation "problem" and may, in fact, be increasing correlations by more or less routinely screening for varieties that perform well in many locations at the same time. More localized breeding endeavors, with more of the selection effort based on performance under more specific agroecological conditions, might help to reduce interregional correlations while improving performance in farmers' fields.

Since several wheat and rice varieties are grown on more than 10 million hectares each, any widespread failure would increase the correlation between their yield variations, as could their similar response to weather conditions common to a large region. The likelihood of such a situation will decline if plant breeding—whether public, private, or in the international research centers—evolves toward greater emphasis on regional and local adaptation.

Inputs are as significant as variety to cereal production and stability, yet they often receive far less research attention. In general, there may be considerable scope for the reduction of variability by more flexible, better informed, and more diversified and specific use of inputs. Farmers may have real informational problems when adjusting to new input-responsive crops or varieties. Their previously accumulated knowledge about yield responses to different management practices suddenly becomes redundant and new knowledge has to be acquired, especially about appropriate input strategies in the event of drought or pest attacks. This information needs to be made available on a timely basis through the agricultural research and extension systems.

IMPLICATIONS FOR AGRICULTURAL POLICY

The difficulties rural societies face in contending with variability of production of their basic staples are probably increasing in many parts of the world if—as is shown in this book for several regions—variability and riskiness of productivity are increasing, and with rapid population growth, greater numbers of people are affected. However, this tendency is more than compensated for in many parts by the moderating influences of better transport and trading systems and by the improved policies and responses that these have made possible.

Another danger is that government policies may cause or exacerbate poor decisionmaking on both investment and resource allocation in areas that are suffering long-term climatic or ecological problems. Intervention should be couched so as not to shield individual decisionmakers from reality, including whatever processes of change in the natural, economic, or social environment may be under way. Related to the possibility of interventions discouraging appropriate learning is the exacerbation of uncertainty faced by farmers. Policy-induced risks may add to the decisionmaking burden of affected individuals—even when policies have the stated objective of mitigating risks.

A fundamental issue facing decisionmakers is the cost-effectiveness of coping with or reducing variability. The ways of coping are diverse—from storage of, trade in, and stabilization schemes for the commodities to insurance, credit, and compensatory finance arrangements. These are not costless, yet neither are the other major alternatives to coping—reducing variability through (1) diversification, (2) infrastructure improvements, including irrigation, and (3) more stable productivity for maize, barley, and sorghum. These differences reflect the various conditions under which the crops are grown. Because so much rice is grown intensively with irrigation or good water control, that crop has some of the lowest yield variabilities over time. Analogously, an increasing proportion of the world's wheat crop is grown under irrigation and with high levels of purchased inputs. At the other end of the scale is millet, typically grown under marginal conditions of low and variable rainfall. There is a tendency in many arid regions for maize to displace sorghum, and for sorghum to displace millet in the least favorable environments—in both cases increasing the yield risk.

SOURCES OF YIELD VARIABILITY

Yield variability is determined by variety (genotype), variability and level of inputs (such as fertilizers, irrigation, and pesticides), and variability in pests and diseases and in climatic factors (such as rainfall, frosts, and temperature). Interactions between these factors are important although difficult to analyze, especially between variety and other factors.

Under controlled (especially in field trial) conditions, modern varieties typically have higher mean yields and absolute variability than unimproved varieties, but their relative variability is either lower or about the same. Similar results seem to hold in farmer-managed trials. Internationally developed varieties of wheat and maize also seem to be more stable than locally developed alternatives under experimental conditions when their performance across contrasting sites (environments) is compared. These favorable results reflect the ability of plant breeders to select varieties that combine high yield performance with stability.

However, stability of modern varieties is not always reflected in farm, regional, or national yield data. There are a number of reasons for this. First, some of the early modern varieties associated with the international agricultural research centers proved to be susceptible to particular pests and diseases. Because of their high yields, these varieties were widely adopted in a very short time and, when pest and disease outbreaks occurred, had a sizable negative effect on farm and aggregate yields. This problem has been contained in recent years by the availability of a wider range of modern varieties, many of which have greater resistance to pests and diseases. Continuing strong emphasis is given to "maintenance" research, whereby replacement varieties are developed and kept in reserve. Pest- and disease-resistance breeding now provides a turnover of varieties in time that has effectively substituted for the large number of traditional varieties used at any one time, and this process seems bound to accelerate with the advent of new procedures in biotechnology.

Conflicting forces may be at work in the changes in yield variability . . . as agriculture becomes more intensive.

Another reason why observed yield variability may increase with the introduction of modern varieties lies in their greater responsiveness to modern inputs. Some modern varieties seem to perform about as well as traditional varieties in poorer environments or under low input conditions, but their yields are much higher under favorable conditions and with greater application of inputs. Consequently, if farmers adjust input use from year to year in response to changes in prices or limited supplies of inputs, this may induce more yield variability in modern varieties. Such behaviorally induced yield variability may have become an important factor, particularly in developing countries. The problem may also have been aggravated by the sharp increases in the cost of fertilizers and other agrochemicals that accompanied the oil crises of the 1970s, and by an increase in the variability of cereal prices in world markets.

A further reason why aggregate yields may have become more variable with the introduction of modern varieties is the increased correlations among yields between farms and between regions. This again may be due to variations in input use, since farmers in the same or adjacent regions are likely to face the same prices and input shortages and therefore make similar adjustments in their use of inputs. The increased correlations may also be related to varietal choice. By screening for varieties that perform well in many locations at the same time, breeders may inadvertently be increasing the chances of greater yield correlation between locations, and hence between farms and regions. This need not be a problem for individual farmers, but it can add to the variability of national yields.

The widespread adoption of a few varieties may also lead to increased correlations through a common susceptibility to pests and diseases, and a common responsiveness to weather conditions. This problem may have been aggravated by a shift toward more homogeneous cultural practices and by an increased dependence on purchased inputs.

Variability in weather is a major source of yield variability, especially for the cereals grown in more arid areas. There is no indication, however, that recent changes in yield variability can be ascribed to climatic change. If anything, weather in some areas may have become less variable. For the future, long-term climatic changes associated with rising atmospheric carbon dioxide levels are likely to have important implications for cereal production variability.

Conflicting forces may be at work in the changes in yield variability under farm conditions as agriculture becomes more intensive. On the one hand, variability tends to fall as control of the crop-growing environment becomes more complete, as in the case of wheat in Western Europe. On the other hand, selection for higher yield potential is dependent on enhanced inputs for the crop and, when these are unreliable, the higher-yielding varieties may be vulnerable to greater variation. For example, as tubewell irrigation for wheat in the Punjab became more widespread, variability fell, while in the Philippines, the limited, uneven, and unreliable irrigation of dry-season rice increased variability (wet-season rice crops were less variable).

Increased yield risks associated with improved varieties or new technologies may hinder their widespread adoption by farmers . . . .

In general, there may be considerable scope for the reduction of variability by more flexible, better informed, and more diversified and specific use of inputs. This will not, however, always be consistent with reducing interregional yield correlations. For example, irrigation that is stabilizing at the local level may increase correlations, thereby having a mixed effect on variability at aggregate levels.