VALUE OF IMPROVED DATA FOR AGRICULTURAL COMMODITY POLICY ANALYSIS, WITH EMPHAIS ON FOOD SECURITY

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Agricultural data are useful to aid better decisions in business, national policy, and international planning and advising. All of these uses demand data that is relevant, accurate, current, and accessible. But, of course, each of these attributes is costly to provide and the creation and distribution of data requires substantial investments. That means we must allocate scarce resources carefully across all data attributes. Among the major choices are who, private or public sources and which agencies, provides which sort of data and how much of which kinds of data will be provided.

Information may have public or private good aspects, but data used in analysis of public policy may be considered a public good, and investments in such data may be evaluated as are other investments in knowledge. Although the role of public organizations, including international agencies, in the development and dissemination of data is well established in general, it cannot be taken for granted. But that is not the main topic here.

This paper has two main themes. First, I will discuss how we may analyze the payoff to investments in policy-relevant agricultural data in relation to the more common practice of analyzing investments in agricultural science. This section concludes with an example of the potential contributions of better data to policy reform and of policy reform to nutritional adequacy and food security. Second, I will discuss the importance of sound economic data to considering food security questions and how relying on production and consumption data alone, and especially domestic production data can provide a misleading picture of food security. Emphasis on domestic food production data in discussions of food security leads analysts and policy makers to think of food security in terms of national or regional self sufficiency and to discount the power of trade to contribute positively to nutritional adequacy and food security. The second part of the paper elaborates on this point.

Before proceeding, I should be clear that this paper discusses the contribution of data useful in agricultural policy analysis. The agricultural data ranges from general economic accounts to information on a specific plant genome that may come from a specific laboratory experiment. The concepts and much of the discussion that follows is general, but the context I have in mind focuses on public data used in public policy making. Even more specifically, the examples I pursue deal with international data provided by public sources that relate to policy of broad global interest. I examine in some detail the prototypical and perhaps the most important global issue for agriculture—food security.

Several organizations provide such data, including universities, industry organizations and national governments. International economic organizations such as the World Bank, the International Monetary Fund, the World Trade organization, and the Organization for Economic Cooperation and Development (OECD) have a major role across all economic sectors including agriculture. Notwithstanding contributions from other organizations, the Food and Agricultural Organization (FAO) is the international institution that has the main mandate for international data related to agriculture. FAO is at the center of global efforts to improve data quality, relevance, and availability.

My discussion here relates directly to only a subset of the available information that FAO provides to the world community. An example of the kind of data that is of immense value is found in the FAO report on undernourishment, "The State of Food Insecurity in the World." No one but FAO can give such data global reach and provide comparisons from one country or region to another. That report also summarizes FAO compilation of a number of variables related to nutritional inadequacy, such as health sanitation and measured nutritional status of children. Data summarized in that report do not, however, provide all the information needed to evaluate policies related to food security. In particular, economic factors underlying undernourishment are explored in case studies not summarized systematically. This paper argues for more attention in that direction and more data from FAO and elsewhere on these underlying economic factors.

Another example of information that is provided uniquely by FAO are the Global Information and Early Warning System reports issued periodically. This information seems to be crucial to timely response to food crises. Further, though the focus in these reports is on immediate issues, they require a baseline of data on the food situation around the globe in order to assess current evolving situations. These reports are not designed mainly to contribute to long-term policy discussion, rather they facilitate better short term response and more understanding of current issues by people in the global community.

A main effort of FAO is, of course, making available a basic global statistical base for production, trade, and related variables on agricultural commodities and processed goods. That is a huge task and what I am arguing in this paper is that these data are even more important than has sometimes been appreciated. I go on to argue for the value of even more data and in particular for more economic data.

A. Investments in policy relevant data in relation to investments in agricultural science

Economists have devoted considerable efforts to assess the contribution of science to agricultural productivity. This line of inquiry generally applies economic reasoning and tools to analyze the costs and returns from agricultural research and extension and, especially, public investments in research. Alston, Norton and Pardey; Huffman and Evenson; and Alston and Pardey, among others, document and represent progress in this area.

Investments in data are much like investments in research. Most investments in better data are an input into further analysis that may (or may not) lead to applications that affect behavior. One of the ways better agricultural commodity data is used is in economic analysis of agricultural policies. In fact, much data collection is expressly motivated by its potential contribution to economic policy.

Systematic discussions of the contributions of better economic analysis to agricultural policy are few and less quantitative than analyses of investments in agricultural science. A pellucid, enjoyable, and insightful essay by Stigler poses and responds to the question, "Do Economists Matter." Part of his contribution is to discuss the role of better data in economic policy. Stigler includes a calculation by Coase that is quite favorable to the overall contribution of economic data and analysis. Nonetheless, Stigler's essay did not seem to stimulate a program of research on the topic. Overall, it is an understatement to say that the economics of policy data is much less well developed than the economics of applied science generally, and this is especially true for agriculture. Recently, papers by Freebairn, Zilberman, and Smith that represent an effort by the International Food Policy Research Institute (IFPRI) have begun to remedy this state of knowledge.

The basic point is that analysis of the costs and benefits of better data for agriculture has much in common with analysis applied to the contributions of agricultural sciences generally. The same statement applied to data dissemination compares, for example, to analysis of agricultural extension services and the dissemination of the results of agricultural science. The rest of this section of the paper documents the similarities and differences between the analysis of agricultural science and analysis of better data applied to agricultural policy, especially food security policy.

A. 1 Agricultural data must be used to be valuable

A general presumption in studies of agricultural research is that research output is itself an input into creation of something that people value directly. That presumption is not strictly necessary. Sometimes good science is aesthetically pleasing and improves human welfare whether or not it is used in a practical sense. Generally we argue that "art" is valuable not in some narrow practical sense, but simply because people enjoy it. In this sense, interesting data can be "art" too. However, data created for simple direct enjoyment is often that which is most historical or literary. As with other fields of applied science, agricultural data useful for policy is only considered aesthetically pleasing by a few of us (mainly other policy practitioners). There are some who may become enthralled by the prospect of beholding a beautiful set of data, but our numbers are small. It is not promising to analyze the payoff to agricultural commodity data as a pure consumption good. Agricultural data shares this important attribute with other agricultural science contributions. Inventing new crops or better farm practices is also not primarily for aesthetics, even if new theories of evolution may be aesthetically pleasing.

Practical agricultural data must (ultimately) affect behavior outside the lab or research institute to have a significant payoff.   A new crop variety that is never adopted has no direct payoff. A specific varietal research project may not lead to adopted varieties, but may lead to future adopted varieties and, if so, its payoff is measured in that context. Practical data generated by agricultural research must lead, somewhere down the chain, to something that is used. In assessments of varietal research we look to higher crop yields, or improved quality, or lower production costs experienced by farmers who have been influenced by research and have adopted a new seed or rootstock.

For data used in policy analysis, the behavior affected may be that of policy makers and thus, indirectly producers and consumers. In that case, we look for improved policy to assess the value of the data. But policy change is not an end in itself, no more than adoption of a new variety is an end in itself. The value of better data is found in measurable consequences that are observable in (explicit or implicit) markets. Second, data relevant for policy analysis may also affect the behavior of producers and consumers directly through improved understanding of policy consequences causing better projections of policy effects. In that case, we look for more efficient responses to policy on the part of producers or consumers. To have a direct payoff, policy data must affect policy or must affect producers' or consumers' responses to a policy.

However, having an observable impact on behavior may be a very long-term process and some policy-relevant data may have little direct effect for a very long time, if at all. That is another characteristic shared by the provision of agricultural data and most applied research.

Studies that are directly focused on a specific issue may have a more immediate impact in any science, but the scope for benefits from such projects is typically smaller. The closer the research is to the perceived needs of specific decision makers the quicker the results may be moved from the research institute to the field. This is true in agricultural science and it is true for data used in applied policy analysis. For example, data designed specifically to advise some Minister of Agriculture about the consequences of a specific level for an export subsidy rate may reduce the welfare cost of such a policy. The benefits may be immediate and definite but of relatively limited applicability, except perhaps as an example. Data on broader or general topics may have wide applicability, but also may have no applicability.

The emphasis on having an impact suggests attention to outreach and accessibility. Some data is directed toward policy makers and advisors, some is most useful to those who influence policy less directly. Education about interpretation of agricultural data may sometimes influence long-term policy reform more effectively than specific data sets themselves. Advanced and sophisticated education of data users is one kind of contribution. A more broad-based contribution derives from education and information related to the principles of sound data interpretation that is directed to the general population in a democracy or to a broad set of those who influence decisions in any society.

FAO has made substantial contributions in all these areas. It is particularly important for an international organization to make its data widely accessible on the web. It is also crucial that the relevant data themselves be timely and considered reliable and objective. That requirement for perceived objectivity is all the more difficult for policy relevant data about which individual governments may be sensitive.

A. 2 Major empirical and conceptual issues are similar across applied sciences

Two major issues are very similar whether we are evaluating the payoff to investments in agricultural research or policy relevant data. This section reviews those issues of linkage and measuring net benefits. I forgo detailed discussion of measuring costs of investments and time discounting, but these are also very similar no matter which investments are evaluated.

Linkage. It is often hard to document the link between the research and the adoption of better agricultural inputs or practices. That is as true for plant pathology and plant breeding as it is for the provision of agricultural commodity data. Showing a direct linkage between better information and a change in behavior may be even more difficult for investments in data used for government policy than for new information related to agricultural science. It is often clear that a specific variety or chemical would not have been available without research. It may often be difficult to specify precisely which research led to a specific chemical or variety innovation, but it may often be very clear that such an innovation would not have occurred without some research.

For practical policy analysis there are several reasons why it is often particularly difficult to link analysis and the data that supports it to the policy change. First, systematic collection and dissemination of commodity data sometimes simply confirms and refines impressions that policy makers may have already formed. That is, better data may not shift central tendencies, but rather reduce standard errors around the estimates about policy impacts. It is a more subtle step to claim that such investments in data are major determinants of policy decisions even though it is often the case that inaction is rationalized on a lack of good evidence. Sometimes data used in policy analysis is devoted to providing evidence for policy proposals that have emerged from the political process without being generated by quantitative policy analysis. In that case, the new data most closely associated with the policy change may have contributed to raising the probability of adoption or accelerating the adoption of some reform. Such a contribution may have large benefits. (See Stigler for an example calculation.) However, it may be particularly speculative to document how much the better data accelerated the policy reform or how much it raised the probability of adoption of a reform that may have happened anyway. There is always a surfeit of claimants when a policy reform is adopted and apportioning the total gain to each contributor is difficult at best.

Measuring the net payoff to reform. Few innovations create Pareto improvements. Even for agricultural research that clearly raises world wealth, and even improves the lot of the poor, some individuals and groups will suffer losses and direct compensation is almost never forthcoming. For example, most scientists and economists laud the contribution of the green revolution to food security for more than a billion people, but there are detractors who argue that these innovations lowered welfare rather than improving it. Some argue that certain new varieties are particularly suited to farms that were already favored or that were owned by the relatively wealthy. In that situation, they argue the poor suffer when a new seed improves the absolute and relative performance of these already favored farms. Distributional considerations complicate the assessments of returns for any innovation.

Agricultural policy reform that increases total social income almost always shifts income between groups. As with biological innovations, there are almost always losers, and those likely to suffer when policy is changed often argue (usually implicitly) that national welfare is reduced with a reform because their well being is more important to national welfare than that of others.

Further, nations often use agricultural policy explicitly to affect income or wealth distributions. Thus, it may be reasonable to argue in some cases that the revealed social welfare function of society indicates which people are favored. Of course, such an argument is based on a view that takes the existing political system as a legitimate reflection of social welfare. In that case, almost by definition, what is is optimal. Policy change only occurs when the constraint set changes, (or is thought to change), when the effective social welfare function itself changes due to some political change, or when new information becomes available. That said, few would argue that food price policy in Africa was optimal when it favored the urban elite to the detriment of the rural poor, because the political system itself was insufficiently representative. In general, however, it remains problematic how to incorporate the existing or potential political structures and outcomes in a social welfare function used in policy evaluation.

The natural approach for economists is to focus on aggregate national income as a welfare criterion even though no nation or social group maintains policies consistent with that social welfare function. But the next step for economists is to argue that the potential for compensation implies that creating aggregate wealth, say through agricultural policy reform, provides welfare gains, and if a society chooses not to redistribute that wealth that is a separable policy choice independent of the agricultural policy reform.

Issues similar to those involving income distribution are often raised in the context of environmental impacts of agricultural innovations. The externality considerations that affect the calculation of returns to agricultural innovations also apply to policy reform. Environmental concerns raised about new varieties or pest control measures are often more troublesome than the concerns raised with respect to policy reform. Indeed, policy reform is often seen to be environmentally benign. Thus, even if better policy relevant data can be shown to contribute to policy reform, evaluation of the payoff is complex.

A. 3 Examples of policy analysis with significant benefits

For applied agricultural sciences, examples from plant breeding are most often cited as examples of research that had clear economic benefit. Beginning with the famous hybrid corn studies of Griliches, through evaluations of green revolution rice varieties, research leading to high yield varieties has been shown to have had very large net benefits.

For policy reform it is harder to point to particular policy analyses that have had comparable impacts. The most famous economic policy research study is the case made for fewer restrictions in international trade made by Adam Smith in the *Wealth of Nations*. One reason Smith's work has had such an impact was his accomplished use of a wide variety of data sources and his command of the best evidence available related to his topics. This comes through strongly, for example in his extended discussions of agricultural productivity, international trade and food security in Europe. In agricultural policy, economic analysis of the distributional effects of agricultural trade restrictions made by British economists of the early 19^{th} century (most famously by Ricardo) helped create the intellectual climate for repealing the corn laws that restricted grain imports. The most lasting of these studies were mainly conceptual and did not rely on detailed use of data, yet their impact on the discipline of economics was enormous. The direct link to policy change is still arguable after about two centuries.

A more recent example that follows the international trade theme relates to the multilateral reforms of agricultural trade policy in the Uruguay Round Agreement (URA) that began to be implemented under World Trade Organization supervision in 1995. The URA for agriculture is generally gauged to have improved world economic welfare by billions of dollars, and one can point to some policy research that likely contributed to the outcome. Sumner and Tangermann and Sumner (1993) discuss some examples. The URA thus may provide evidence for the role of economists in more liberal agricultural trade policy.

Perhaps the most important contribution ever of an identifiable agricultural policy change was the reform of the Chinese system of collectivized farming. The shift to the household responsibility system reduced human suffering on a massive scale by allowing market incentives to help create more food and opportunity for hundreds of millions in rural China. These reforms were certainly consistent with the thrust of western economic ideas (Lin). However, it is hard to point to evidence that the Chinese regime used these ideas or that any particular data or policy analysis contributed to the policy innovation.

***A.4 Ex ante* evaluation of productivity versus policy innovation**

If we have a model or method for evaluating contributions of investments in agricultural data or applied research, then we can also use this model for *ex ante* projections of costs and benefits, and therefore for allocation of research and outreach funds across programs and projects. Such *ex ante* evaluation *always will* be done (explicitly or implicitly). The research budget will be allocated. Relevant questions are: who will do the analysis? How systematic and sophisticated will it be? And, how will evidence be used in decision making? These same issues arise in the allocation of funds for the collection, dissemination and analysis of agricultural commodity data.

Important administrative choices about data projects relate to how much funding to provide, which locations to focus upon, which commodities to survey, which statistics to collect, and how much to devote to dissemination or analysis relative to data collection.

These same issues relate to other agricultural research. As usual, factors in the evaluation and *ex ante* net returns calculation include: cost of the project, likelihood of success, likelihood of adoption of the results, schedule of adoption, and net payoff to the adoption for the adopters and for society generally. These issues and the difficulties they raise are very similar whether the *ex ante* allocation decisions are among plant genetics projects that contribute to improved crop yields or among commodity data collection projects that contribute to policy data and analysis. They also apply to choices between funding agricultural data, plant genetics research or economics research.

An example will help illustrate the similarities between evaluating the payoff to policy analysis and biological research leading to new varieties. In order to make the discussion of tradeoffs more explicit, I will set this discussion in the context of *ex ante* evaluation. To help fix ideas, I take the simplest possible policy question and analysis. Nonetheless the example chosen is relevant to real food security issues.

First let us consider equilibrium in a commodity market situation that has a common agricultural policy in place. Then we will consider the effects of introducing an agricultural productivity innovation stimulated by an investment in plant genetics or an innovation in policy that is stimulated by an investment in better policy-relevant commodity market data.

In figure 1 the commodity market has a demand function labeled Demand. The initial marginal cost of domestic production is represented by the curve S_0, which starts at marginal cost Pmin and then after a short horizontal segment proceeds along the upward sloping portion of the curve. The potential import price of the commodity is P_w, but in the initial situation imports are banned.

Now, let us evaluate the projected benefits of genetics research applied to this commodity market. Let us assume the research will be a success in that, in accordance with the objectives of the project, the research results will be adopted by producers and that yields increase and marginal cost of production falls relative to the pre-research situation. The direct impact of plant breeding research is shown in figure 1 by a shift of the marginal cost function down and to the right. The new marginal cost curve is shown by S_1. For simplicity, I leave the minimum marginal cost at Pmin, but the horizontal segment of the curve now extends a bit further to the right. For simplicity, let us assume that the plant breeding research has no effect on government policy so that imports are still not allowed. Market price in this country now falls from P_0 to P_1 and consumers benefit from the price decline.

How we view the social benefits from this research may depend on the total gain to society relative to the initial position, but our views may also be influenced by the distributional impacts. In figure 1, consumers gain from a lower market price and producers gain so long as the area between the two marginal cost curves is larger than the profits forgone from the lower price. Producer gains are more likely the higher the elasticity of demand (in absolute value) and the lower the elasticity of supply. Note there are also large data demands in evaluating the genetics project and both physical and economic data are required.

Figure 1 has focused on the distribution of annual income flows. We have not discussed the costs of research or the timing of the benefits flow. For simplicity, assume that the varietal research that shifts the marginal cost function can be achieved for a cost of $1 million per year expended during 10 years, t - s , s= 1,…10. Further assume, in order to complete the calculation, that the social gain equals $2 million and the effect of the research lasts from year t + 1 to year t + 10. With this information we may calculate an aggregate net return or evaluate the payoff of this research relative to some target rate of return.

Now imagine that an administrator or funding agency has to decide between allocating a budget for 10 years between the expenditure on plant breeding research and an identical expenditure on data collection and analysis that facilitates policy reform. Assume for simplicity that the outlays on data necessary for successful policy reform would be exactly the same as those for the genetics project.

As with the genetics project, let us assume that if funded, the data project will be successful and the implication will be a change in the policy. In this example, as is often the case in practice, the crucial input into practical and convincing policy analysis is better data on relevant variables. For example, assume that with additional funding we are able to collect reliable data on the domestic and international price distributions and estimate needed elasticities that allow one to quantify the net loss and distributional impacts of the import barriers more precisely. The effect of this work is an adoption of policy reform, just as in the plant breeding example the effect of the work was a change in grower adoption of varieties.

As with the plant breeding project, the policy change would affect both overall social income and the distribution of income. In this case, there is a large gain for consumers as price falls from P_0 to P_w. But, now domestic producers lose from a lower price and a lower domestic quantity produced. Society as a whole gains the large triangle bordered by S_0 and the demand curve down to the base at P_w.

If the time path of benefits from better policy data are the same as for the plant breeding project, then the investment in better commodity market data and the resulting policy reform has a larger payoff than the genetics project if and only if the smaller triangle bordered by S_1 and the demand curve down to the base at P_w is larger than the area between the two supply curves from Pmin to P_w.

It is instructive to consider how our ranking of projects might be affected by issues other than net present value of national income. From figure 1 it is clear that consumers of food would prefer funding the data project while producers would lose from the policy reform. Which project is chosen might hinge mainly on the welfare or political weights applied to the change in income or wealth of the competing groups. Note also that the benefits of the better data and the resultant policy change would be smaller if the plant breeding research was undertaken first and supply function S_1 applied to the question of the benefits from policy reform. Likewise, the benefits of the genetics project would be much smaller in an open trade environment. It is probably a waste to pursue the plant-breeding project if most of the consumption will be coming from imports anyway. Therefore, in this example, the social incentive for pursuing each innovation is smaller if the other is also achieved.

Food security and nutrition implications from this example may also be usefully discussed. For a small country importer, this example shows that investment in local agricultural productivity does nothing for access to food for the population. At best these innovations improve the returns to owners of farming resources and thus may add to the income of this segment of society. In some cases, such individuals are themselves vulnerable to food shortages and hunger and thus aid to them can be positive for food security. But, if the cost is raising the price of food to the whole population the trade off is almost surely negative for national food adequacy.

Of course, the example does not represent the full analysis of the potential benefits from policy-oriented commodity data projects. Recall that commodity data also allows private agents to better optimize, whichever particular policy is in place. Data projects may provide forecasts of prices and other variables that are conditional on the maintenance of a particular policy. Accurate projections based on policy assessments reduce losses from misallocation of resources that would arise if incorrect price information were used. Stated another way, policy research may reduce the search costs for producers or others who have a demand for accurate projections. Benefits from market projections tied to public policy analysis are similar to other private data and forecast services and evaluation would proceed similarly. It is not clear that this activity has a direct parallel with plant breeding research.

A.5. Remarks

The key point of this section is that there is little difference in kind between evaluating the returns to applied agricultural science research and investments in policy-oriented collection of agricultural data. Empirical evaluation of benefits is difficult in both cases and each must be based on a willingness to use approximations and assume linkages between investments in new information and the practical outcomes outside of the lab or computer center. For some research, the outreach audience is farmers and other private managers. For policy-relevant data the audience may include private firms, but also includes government officials, economic analysts and other participants in the policy process. In each case, the research must be useful and used to have a significant payoff to society.

The discussion based on figure 1 illustrated by example the considerations important for *ex ante* evaluations of the allocation of funds between better policy-relevant data that leads to policy reform and applied agricultural science research that leads to lower output costs per unit. This illustration further shows how application of investments in one area may reinforce or subtract from the value of investments in the other area.

Evaluation of the contribution of public agricultural investments is complex. But *ex ante* evaluations will be conducted. The question is how well they are conducted so that investments in data are appropriately weighted in the calculations.

B. Contribution of more and better data to analysis of food security policy

Food security is a stated objective of agricultural commodity policy in virtually all countries. Rich and poor, importer or exporter all governments seem to state food security of their population as an objective for agricultural policy. The range of internal and border policies tied to food security objectives is equally impressive. Subsidies for research, income redistribution, rural infrastructure, price floors, price ceilings, import barriers and export subsidies are all explained as part of food national security policies.

In the United States, as recently as the 1985 the law that renewed farm commodity programs and related policies was titled the Food Security Act. In China, food security is often listed as the key objective of state trading in grains and policies to encourage self-sufficiency for the nation and even for individual provinces. In South Korea, food security is listed as a primary reason that agriculture must be a special case in WTO negotiations.

This section has a few limited objectives all leading to a discussion of the role of better data for use in understanding food security and the influence of policy. First I define and discuss an operational “Index of National Food Security” (INFS) that may be readily measured and related to agricultural commodity data. This section of the paper is based on a recent report, Sumner (2000). This index makes explicit data demands that provide intuitive connection between commodity market data and analysis of food security. The role of FAO data in compiling such an index and understanding food security or vulnerability is the final topic of this section.

Throughout this section, I make only limited reference to the vast literatures on food security. Fortunately, some recent survey articles deal with many of the important issues and provide many useful references. Duncan provides an assessment of the current status of global food adequacy and patterns and prospects for food security. See also FAO, 1999 and data provided at www.fao.org. Barrett reviews food security definitions and relates nutritional adequacy to food security for vulnerable individuals. He also reviews the evidence on domestic and international food aid. Sumner and Tangermann review aspects of agricultural trade policy and the WTO that are relevant to discussions of trade policy and food security.

B.1 An operational index of national food security

The concept of food security is as complex as it is fundamental. As with many basic ideas, "food security" seems intuitively simple yet turns out to be analytically complex once we begin to examine the idea in some detail. First, there are complex biological and economic connections between food demand and nutrition. Second, food security means more than a current absence of hunger or even the current possession of nutritional health. Food security concerns potential food intake into the future and is thus inherently dynamic. And, as implied by the word "security," any concept of food security must include the stochastic nature of food supply and demand and therefore a probabilistic notion of future nutritional status.

Define a threshold food intake f_i* above which a person, i, has adequate nutritional health. This means that the person has satisfied whatever standards are considered appropriate based on demographic, exercise or medical conditions. This threshold may be similar to that used by FAO, 1999 table 1. That said, when we consider national policy, we acknowledge that different countries may define the threshold diet differently for food security considerations.

Given the threshold of adequate food intake, the index of food security for an individual may be defined as the likelihood that food intake remains above that threshold. Thus, the degree of individual food security at time n (for now) may written as,

$$FS_{in} = prob_n\ (f_{it} > f_i^*), \quad t > n.$$

This definition focuses on the probabilistic nature of food security and does not recognize degrees of nutritional adequacy during a period as contributing to additional degrees of food security. This is also implicit in FAO, 1999. Also, by leaving aside any time discounting, this definition treats food shortfalls as equivalent independent of when in the future they might occur.

Recognizing that some parts of the population may be particularly vulnerable, the distribution of food intake across the population is as important as average intake. To focus on this vulnerability, let us define the degree of *population* food adequacy as the share of the population consuming at least the minimum food required for nutritional health. That is, population food adequacy, Fa_t is measured as the probability that an individual from the population has $f_{it} > f_i^*$ (again, see FAO, 1999). And, of course, the food intake distribution across the population is often closely related to the income distribution.

This definition treats population nutritional adequacy and adequacy of food intake as pure threshold concepts. By this definition, we are not able to consider degrees of under nourishment or hunger. But, for simplicity and without losing too much empirical applicability we will stick with our purely threshold concept measuring population food adequacy as simply the share of the population with adequate diets.

Now, we must add the stochastic nature of "security" to our notion of population food adequacy. Food security of a population is naturally related to the definitions just proposed. We link the share of the population with an adequate diet during some period with the probability of achieving that adequate diet in the future. *Our operational definition of the index of national food security is the probability that some given share of the population will be able to achieve an adequate food intake in the future.* Note all three parts of our analysis, individual food adequacy, a share of the population and the stochastic nature of food supply and demand, each have a role here. (I prefer the term food security for this index, though some may wish to use the term "vulnerability" to refer to the chance that negative events affect nutrition in the future.)

To summarize, adequate individual food intake is $f_{it} > f^*$ where i ranges over individuals and t ranges over time periods. For some given time period we can define the share of the population for which $f_{it} > f^*$ as Fa_t. It is reasonable to think of the distribution of income in the population as a main determinant of the distribution of f_i in some time period. Next define a threshold share of the population Fa^* as defining national food adequacy. This threshold acknowledges that it may not be possible to eliminate hunger or the possibility of inadequate diets for some share of the population over the relevant trade policy horizon, but that in every country, if the share of the population suffering food inadequacy is too large, as defined within that country, policy makers are willing to say there is an issue of nationwide food inadequacy. The stochastic future is introduced by defining the Index of National Food Security as the probability that $Fa_t > Fa^*$ in the future. This index may be measured using the probability distribution of future events that affects food intake among those individuals most vulnerable to food shortfalls and is defined for each country as:

$$INFS_n = Prob_n (Fa_t > Fa^*), \quad t > n.$$

B.2 Food supply and demand and food security

Food demand for individual i in period t, may be written as a function of the price of food and income and other factors,

$$f_{it} = f(P_{it}, I_{it,} Z_{it}) ,$$

where for simplicity explanatory variables such as demographic characteristics and relative prices of other goods are subsumed in the Z term. I have also suppressed an error term that would reflect unmeasured determinants of food demand. We may consider P_{it} as mainly exogenous to the household or individual and, as a simplification, we might think of P varying mainly over time and less across individuals. Income does vary widely across individuals and is endogenous. In many countries income is mainly based on labor market earnings. In poor rural populations the income of farm households who may sell food is important for food security. Therefore write,

$$I_{it} = P_{it}Q_{it} + V_{it},$$

where Q is home production of food and V reflects earnings from other occupations including production of non-food agriculture. We have simplified the contribution of food production to income by simply valuing home-produced food at the same price used in the demand function. For many individuals Q is zero, but for many rural households a significant share of family income in created by direct production of food. Also, of course even for farmers, Q_{it}

may be greater than or less than f_{it} meaning a farm household may be either a net buyer or seller of food.

Here I use the relative price term to reflect the full opportunity cost of food intake and the income term to reflect command over resources that could be used to acquire food. This income term includes the value of home-produced food and other goods or services as well as wages that are paid in kind.

Holding price constant, the distribution of f follows from the distribution of income or the distribution of Z. The functional form of the demand equation implies a specific relationship between the income distribution and the food intake distribution and more income means more food intake, and almost certainly a lower share of income spent on food. For the threshold f*, which defines adequate food intake, there is an income I* which is the threshold income required for adequate food intake, holding price and other variables constant. That is, the share of the population with less than adequate food intake, again with other variables constant, is the share of the population with income below I*.

Next, consider the distribution of P over time, conditional on income and other variables held constant. Here we think of the distribution of P as reflecting the randomness inherent in agricultural markets. Unanticipated variation in P_t follows some probability distribution. Now, with the exogenous distributions of other variables fixed, food intake relative to the threshold food intake quantity f* is just a function of P. Now consider how price affects the share of the population with $f_{it} > f^*$, Fa_t. Figure 2 shows how the value of Fa_t relates to the price of food for given distributions of other variables. Notice that Fa_t ranges between zero to one, because it is a share of the population, and P_t is restricted to be positive. The probability distribution of Fa is a transformation of the probability distribution of P.

Figure 3 shows the relationship between the probability distribution of price and the probability distribution of Fa. As in figure 2, a low price is mapped into a high share of the population with an adequate food intake and a high price is mapped into a low share. Share Fa* is defined as the threshold population share below which a country acknowledges widespread inadequate diet.

In figure 3, the INFS is the area under the density for Fa to the right of point Fa*. This is equivalent to the area to the left of P* in the density function for P. Equivalently we may say that the probability of a widespread national food shortfall is shown by the area under the curve to the right of P* or to the left of Fa*.

B.3 Data for the Analysis of National Food Security Policy

The INFS depends on the parameters of the distributions of prices and incomes in the population among other variables. Understanding food security requires data on many variables. These include: income distributions across the population, income shares spent on food or the staple crops, shares of income of farm people received from sale of food commodities, size and income position of this farm population, and, crucially, data on commodity prices that allow us to measure prospective probability distributions of prices under alternative policies and market conditions.

One may easily show analytically and with simulations that any policy or event that increases the income of the poor raises INFS. Such policies may be those that improve national average incomes or policies that shift income specifically to the poor who make up the left tail of the food intake distribution. Policies that make incomes less variable over time also reduce the chance of widespread food shortage and thus raise INFS. Cross-national observations demonstrate clearly that the most important strategy for national food security relates to economic growth and widespread improvement in income. Thus, any food security policy must be evaluated against what it does to economic growth and particularly the opportunity for improving incomes of the poor.

Agricultural commodity policies affect incomes, but even more directly these policies often affect the price of food. In figure 3, we see that a shift to the right in the probability distribution of the price of food, say because of an import tariff, lowers the probability that the threshold share of the population will have an adequate diet and thus reduce INFS.

However, in some very poor agrarian populations, farmers make up a large share of the poorest part of the population and these farmers derive a large share of their income from production of staple grains. For those who consume all or almost all their production at home, high food prices provide no help, and for those who purchase food, high food prices are positively harmful to their real income and the relative price of nutrition. Nonetheless, for that segment of the rural poor who sell a significant share of their output, high food prices can, in theory, raise their income enough to shift out the share of the population with an adequate diet at any given price, and shift out INFS. The lesson of this case is that in analyzing food price effects of trade barriers we must be sure to include the effects on the incomes of the rural poor who sell food. That means that demand for good data is even more compelling.

FAO already assembles much of the data necessary for calculation and analysis of INFS and other measures of food security. Indeed the FAO website has become the global source for systematic and conveniently available data on food consumption, nutritional outcomes, food production, and selected other variables.

The biggest challenges are data on economic variables. For example, in order to calculate INFS and to analyze how it may be affected by various policies, one must be able to characterize income distributions and how they are affected by various events and policy changes. FAO does collect and report income data, but even more effort to assemble such information may be appropriate. Commodity price data for staple crops is even more important and perhaps even more challenging. For analysis of food security we need to have both price faced by consumers and prices faced by domestic producers under alternative policies. Further, to capture the stochastic nature of food security we need to represent probability distributions of prospective prices under alternative policies. This implies that we need up-to-date price series for domestic prices and international trade prices. FAO now provides some of the needed data, but it is much harder to maintain reliable price data and to keep it up-to-date than it is for quantity data.

Conclusion

This paper has argued that good data is a crucial input to improved food security. I have documented how analysis that applies to measuring the payoff to investment in agricultural science also applies to agricultural data. I argue that sometimes the payoff to better data may outweigh the payoff to local agricultural productivity. Finally, I have argued that to analyze national food security we need more and better information on economic variables such as income distributions and commodity prices.

FAO has made remarkable contributions by assembling and disseminating agricultural data. The FAO website is now the central source for such information on a global basis. But such work is never complete and even more data investments would have substantial payoff.

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Figure 1
Returns to cost-reducing innovation relative

to policy reform

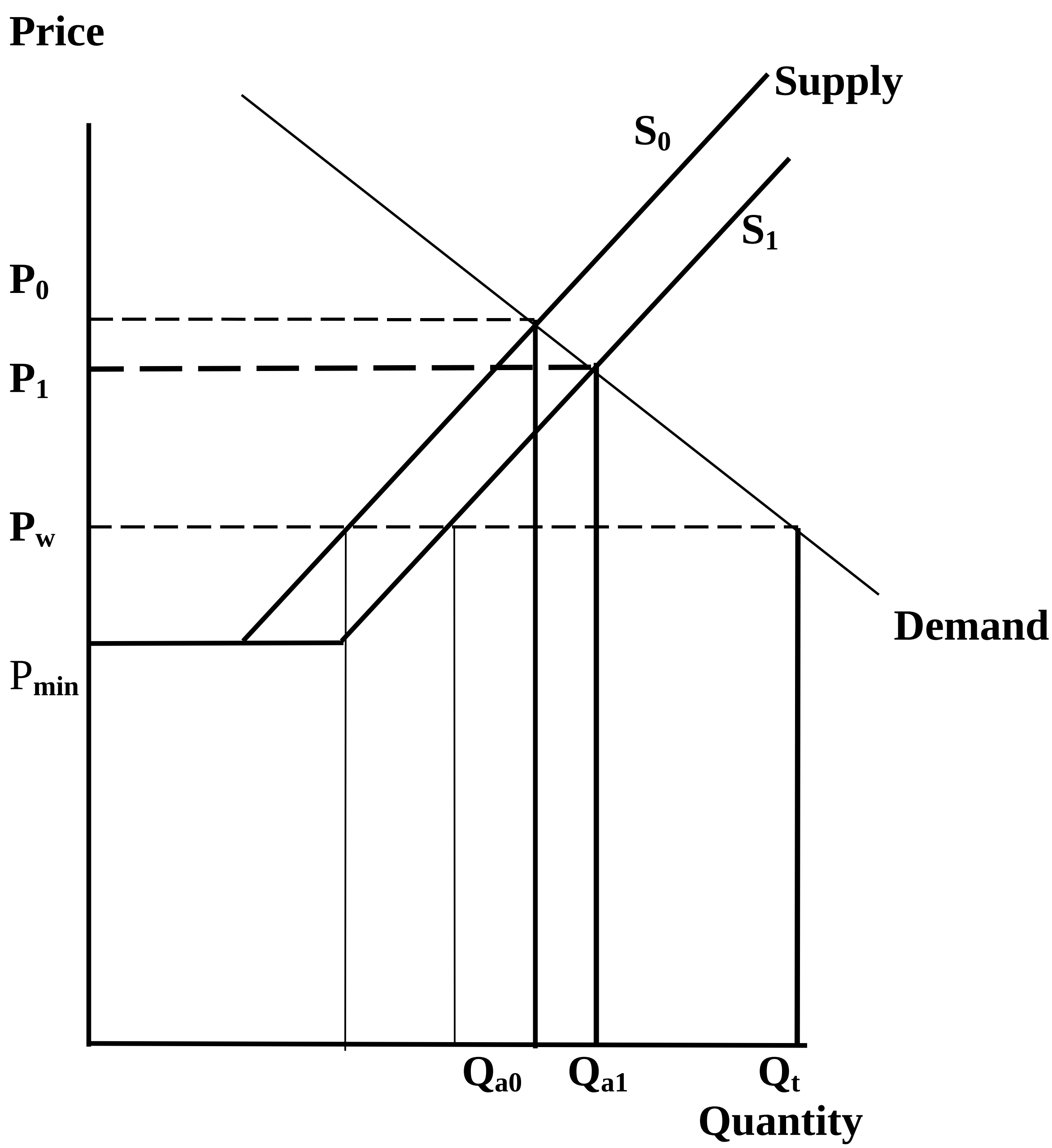

Figure 2: Functional Relationship between Food Price and the Population Share with Adequate Diet

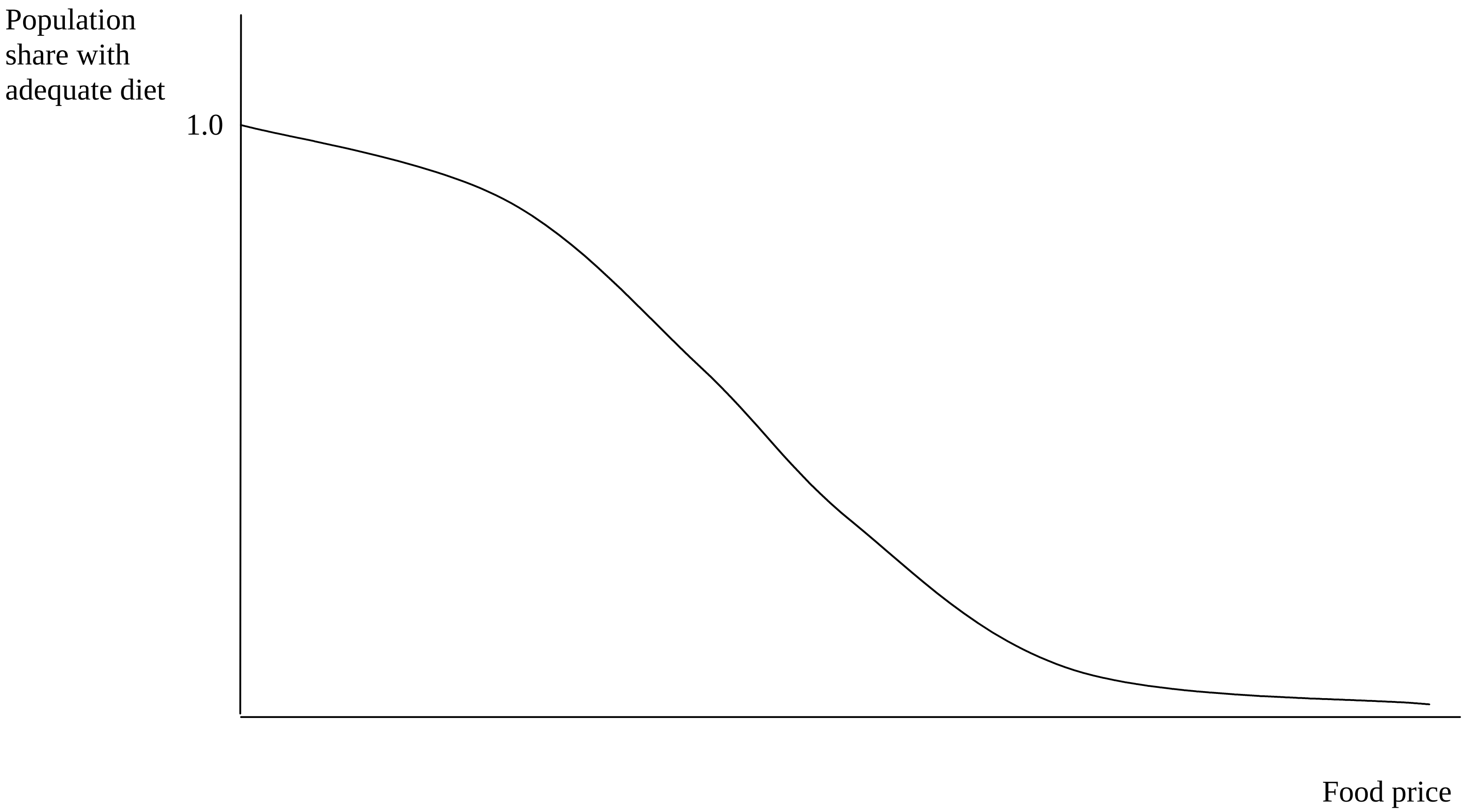

Figure 3: Probability Density Functions for Food Price and the Share of the Population with an Adequate Diet