EPTD DISCUSSION PAPER NO. 56

IMPACT OF AGRICULTURAL RESEARCH ON POVERTY ALLEVIATION: CONCEPTUAL FRAMEWORK WITH ILLUSTRATIONS FROM THE LITERATURE

John Kerr and Shashi Kolavalli

Environment and Production Technology Division
and
Food Consumption and Nutrition Division

International Food Policy Research Institute
2033 K Street, NW
Washington, DC 20006 USA

and

Impact Assessment and Evaluation Group
Consultative Group on International Agricultural Research

December 1999

This paper was prepared as part of a project titled "Impact of Agricultural Research on Poverty Reduction", which is being undertaken by IFPRI on behalf of the Impact Assessment and Evaluation Group (IAEG) of the CGIAR. Funding was generously provided by the Governments of Australia, Denmark and the Netherlands, the International Fund for Agricultural Development (IFAD), and the CGIAR Co-Sponsors: FAO, the World Bank, UNDP and UNEP. An earlier draft of this paper was presented and discussed at a methodology workshop organized as part of the project in May 1999.

EXECUTIVE SUMMARY

More than 30 years after the green revolution brought new, high yielding cultivars to farmers in developing countries, rural poverty and low food intake still plague many countries throughout the world. Many people question the role of agricultural research in alleviating poverty, arguing that it favors wealthy farmers over poorer farmers and laborers. On the other hand, the record shows that research-led technical improvements have contributed to a three-fold increase in food production in developing countries, helping avert what some observers had predicted would be chronic, widespread famine throughout the developing world.

This paper reviews the literature on the subject of the role of improved agricultural technology in alleviating poverty in developing countries. Focusing primarily on improved cultivars produced by the international agricultural research system, it shows how new technology combines with other socioeconomic and institutional factors to determine poverty alleviation outcomes. Technology's role in alleviating poverty is both indirect and partial; technology alone cannot overcome poverty, nor can continued poverty be blamed on improved technology.

The review is organized into three parts in addition to the introduction and conclusion. Part I introduces poverty (Chapter 2) and the achievements of agricultural research (Chapter 3). Chapter 2 summarizes the extent of world poverty and how it is distributed across and within different regions of the world. It focuses on poverty defined in terms of material deprivation and low per capita income since the international agricultural research system was mandated to reduce poverty defined in this way. The chapter also introduces notions of poverty related to broader measures of well-being and empowerment; a separate review will be conducted to examine the relationship between research led-technological advances and various measures of empowerment.

Chapter 3 describes the outputs of agricultural research and documents some of its achievements. The well-known green revolution enabled vast increases in crop yields and output in developing countries, but the early modern varieties had a narrow genetic base and their performance was highly dependent on irrigation and chemical fertilizers, pesticides and herbicides. Since then there has been considerable success is in developing cultivars with more broad-based genetic composition whose yields are less sensitive to irrigation and other inputs. As a result, rainfed areas of India that adopted improved varieties in the 1980s exceeded the original irrigated area covered by the green revolution in the 1960s. Performance will always be superior with better use of inputs, but recent technical improvements give cash-constrained farmers in unfavorable areas better opportunities to raise their production greatly.

Part II provides a conceptual framework and evidence from the literature for the link between new agricultural technology and poverty alleviation. It takes a historical perspective, examining evidence from the literature. The discussion simplifies the complexity of the relationship between technological change and poverty alleviation by breaking it into four types of linkages: i) distribution of benefits across farms with different resource (particularly land) endowments, ii) distribution between farmers and laborers, iii) effects on food availability and consumption, and iv) impact on broader economic growth and employment. It is important to remember that many if not most rural households in developing countries are simultaneously sellers and buyers of food and labor, so changes in agricultural prices have competing effects on their overall incomes. For such households these linkages must be examined jointly.

Following the conceptual framework (Chapter 4), Chapters 5-8 provide evidence on each of the four linkages listed above, respectively. The main findings are as follows:

1) Population gains have obscured the tremendous increases over the years in the volume of food that developing country agriculture produces and the number of people it employs. Total cereal production in developing countries has increased three-fold since 1961, primarily through yield increases (FAO database). This has undoubtedly raised food availability and kept food prices low, providing critically important benefits for extremely poor households that spend more than half their income on food. However, these benefits are dampened by the fact that the total population of developing countries has more than doubled during the same period of time. Similarly, agricultural

employment in developing countries grew by about 60% during the same period, but because the total work force more than doubled the benefits are not easily apparent. The proportion of people who are poor has fallen significantly but, with population growth, the absolute number of poor people has not. It is difficult to eliminate poverty when most babies are born into households headed by parents with very low income, education or job skills.

2) Effects of improved technology on income distribution across farms with different resource endowments have been ambiguous. It is easy to find both cases in which poor farmers with small land holdings have benefitted as much as large farms, and those in which the benefits of new technology were confined to wealthy, more commercialized farms. Which outcome predominates depends primarily on the underlying socioeconomic conditions of a particular case rather than the characteristics of the technology per se. In particular, more equitable outcomes are more likely if land and income are relatively equally distributed and, markets, government services and infrastructure are well developed. Unfavorable social outcomes are more likely when these conditions are not in place.

3) Similar issues surround the distribution of benefits of new technologies between farms in favorable and unfavorable agroecological regions. If new cultivars require irrigation, for example, farmers in irrigated areas who adopt them may become better off while those in rainfed zones may suffer declining income. This is because higher overall production would reduce output prices. For adopting farmers production increases could compensate for lower prices, but nonadopting farmers would receive lower prices for the same level of output as previously. Evidence from Asia suggests that over time, farmers in nonadopting regions shift to other crops in which they have a comparative advantage. Some workers migrate from the nonadopting to the adopting areas where labor demand has risen, reducing regional wage differences. Inequitable impact across regions is a reality, but there is a certain inevitability

about this due to the importance of agroclimatic conditions in agricultural production.

4) Evidence on changes in employment and wages resulting from technical change is complicated. Improved varieties raise employment, though this effect has weakened considerably since the initial introduction of green revolution varieties in the 1960s. Changes in real wages resulting from increased demand are difficult to track for at least three reasons. First, wages in the nonagricultural sector play a role in determining agricultural wages; second, economic policies influence wages; and third, steady growth in the population of unskilled job-seekers and migrants counteracts the demand effect.

5) Agricultural productivity growth can stimulate wider growth in the nonfarm rural economy, which in turn can contribute to poverty alleviation. However, poverty alleviation through economic growth takes time and depends on favorable conditions such as relatively equitable initial division of assets, widespread access to infrastructure and government services, and promotion of labor-intensive enterprises. While economic growth is not sufficient to alleviate poverty, evidence suggests that it is necessary. Alongside economic growth, poverty alleviation requires special programs targeted to poor people to provide safety nets and give them opportunities.

Part III looks ahead to the future. It examines potential opportunities to focus agricultural research specifically on the needs of poor people. Chapter 9 discusses the prospects for designing technical characteristics of new technology in a way that would favor poor people. This could be done by developing seeds with favorable nutrition features, working on crops that poor people typically consume, or working in areas with a large population of poor people. Two schools of thought are sharply divided on this issue. One argues that targeting research objectives to specific poverty-alleviation objectives would have a high opportunity cost in terms of foregone productivity increases, which are critical to poverty alleviation for reasons explained in Part II. The other school of thought points out that many other poverty alleviation measures, such as various development projects and food supplementation efforts, have had poor performance at a very high cost, so it may well be that targeted agricultural research could be more cost-effective.

Chapter 10 introduces participatory research and the possibility that poor people could have a greater say in the research agenda and the research process. Participatory research may facilitate improved performance in developing new technology for complex agricultural systems in unfavorable agroclimatic zones, which often have a high concentration of poor people. To date there has been little evaluation of the performance of participatory research, but it is an emerging area and the literature about it is growing.

Chapter 11 discusses the possible implications on poverty alleviation of two recent developments in agricultural technology, biotechnology and precision agriculture. Unlike the green revolution, which was sponsored and executed by the nonprofit and public sectors, biotechnology is controlled by profit-making companies in developed countries. They focus on the scientific needs of highly commercialized agriculture, where farmers can afford to pay top dollar for new technologies. Biotechnology probably has great potential to help solve the problems facing poor farmers in developing countries, but to date there has been relatively little work in this regard. The Rockefeller Foundation's major program on rice biotechnology in Asia is a notable, welcome exception. Harnessing the potential of biotechnology to solve developing countries' needs, particularly in unfavorable, less commercialized areas, will require innovative collaborative efforts between developing country agricultural research systems and the private companies that dominate biotechnology.

Chapter 12 focuses on research to assess the impact of agricultural research on poverty alleviation. Such evaluation efforts must overcome measurement difficulties associated with the fact that the relationship is indirect, with numerous confounding factors. Ideally the analyst would have data on conditions both before-and-after and with-and-without the introduction of new technology. This helps ensure that changes in poverty conditions are properly attributed to all of the actual determinants, including technology change but also other factors. There is also scope for introducing quasi-experimental design to control for confounding factors. This has long been used in nutrition studies but is only just emerging in economic analysis.

Research to assess the impact of agricultural research on poverty alleviation can be particularly effective by combining quantitative and qualitative research methods. Quantitative approaches are needed to analyze complex, indirect relationships regarding poverty reduction, while qualitative approaches can help understand poverty from local people's point of view, capturing important relationships that outsiders might overlook.

Knowledge Gaps

Comparatively few studies reviewed in this study even acknowledged the various confounding factors that can influence poverty outcomes, let alone control for them. Even when they did try to do so, there was little comparability across studies because they used different methods, asked different questions, and defined their problems differently. As a result, reviewing the literature involved piecing evidence together as well as possible, and room for debate remains on some important questions.

Answering some lingering questions will require a set of studies using common methodology, both quantitative and qualitative. This would help isolate causal relationships between new technology and poverty alleviations while also spelling out conditions under which they do or do not hold.

The problem of confounding factors is perhaps greatest regarding the distribution of income across different types of farms and between farm and labor income. This is also the topic on which there is the most literature arguing that new technology has negative distributional outcomes. A coordinated series of studies on these relationships would be particularly useful.

Despite the apparently unequivocal successes of agricultural research in making food more available and less expensive, some critics would argue that if lower food prices come at the cost of lower wages and lower incomes for poor farmers, then they merely serve to justify and maintain an unfair system that keeps poor people poor.

Accordingly, there is a need for additional, coordinated studies that jointly examine both the production and consumption consequences of improved agricultural technology.

One specific point on which there is little or no evidence is whether the approach to research (rather than just the products of research) affects poverty. For example, evidence is weak on the impact of participatory research, and what little information is available focuses on technology development and adoption, not poverty alleviation.

As mentioned above, controversy surrounds the issue of targeting agricultural research to explicitly address poverty concerns. Past experience shows many cases in which attempts to design technologies with pro-poor characteristics were costly and ineffective, so new efforts must proceed with caution. On the other hand, attractive opportunities may exist and it may be useful to test them on a small scale under conditions where they do not compete for resources with research that focuses on traditional productivity objectives.

CONTENTS

ACKNOWLEDGMENTS

A draft of this review was prepared for the IFPRI workshop on the Impact of Agricultural Research on Poverty Alleviation, May 12-14, 1999.

Jock Anderson, Derek Byerlee, Alain de Janvry, Lawrence Haddad, Peter Hazell, Louise Shaxson and Tom Walker made helpful comments on earlier drafts. The paper also benefitted from numerous insights arising from discussions in the IFPRI workshop.

Ghada Shields provided valuable help in finding data and locating references and preparing figures. Tricia Klosky helped obtain reference materials and Beverly Abreu prepared figures. Michael Loevinsohn and Steve Franzel were kind enough to respond to our request for recent literature on the impact of participatory research.

IMPACT OF AGRICULTURAL RESEARCH ON POVERTY ALLEVIATION: CONCEPTUAL FRAMEWORK WITH ILLUSTRATIONS FROM THE LITERATURE

John Kerr and Shashi Kolavalli*

1. INTRODUCTION

Publicly-funded agricultural research in developing countries receives about eight billion dollars annual expenditure, of which about four percent comes from the Consultative Group for International Agricultural Research (CGIAR). This research has produced several types of outputs, of which the best known are modern varieties for staple food crops. Broadly speaking, agricultural research outputs can be classified into 1) genetic material for crops, trees, livestock and fisheries, 2) new management practices that raise output or conserve resources, and 3) a better understanding of the socioeconomic and political factors that enhance the productivity and poverty-reducing impacts of new technologies and management practices.

Despite a broad array of achievements, the impact of agricultural research on poverty alleviation is a source of some controversy. Proponents point to a large body of evidence showing that this research has been instrumental in introducing improved technologies that have raised agricultural production, stimulated economic growth, and helped poor people through lower food prices and higher incomes (Lipton with Longhurst 1989; Tribe 1994). Agricultural technologies have helped food production grow faster than population, thus avoiding widespread food shortages that would cause particular hardship on poor people (Plucknett 1991). Not surprisingly given these achievements, analysis suggests that agricultural research is one of the most economically productive investments that a government can make (Alston et al. 1998).

In contrast to this optimistic portrayal of the impact of agricultural research on poverty alleviation, there are concerns that research-led technological change in

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* John Kerr is Assistant Professor at Michigan State University and Shashi Kolavalli is a consultant working out of El Dorado, Kansas.

agriculture has favored wealthy farmers at the expense of poor producers and laborers (Freebairn 1995). For example, wealthy farmers may adopt new technologies more easily than poor farmers because they have better access to information about the technology, better access to cash or credit to purchase inputs, or more capacity to bear risk. Some technologies, such as agricultural machinery, may be more profitable on large farms than small. In addition, machines can displace workers, causing wage incomes to fall for the poorest people in the agricultural sector. Benefits from research may differ not only within but also across regions. For example, they may raise production in high-potential areas with favorable soils and rainfall but not low-potential areas, which may become absolutely worse off if higher aggregate output causes prices to fall. Under these circumstances, technical change in agriculture may increase poverty, not reduce it.

Using illustrations from the literature, this review presents a framework for understanding the relationship between agricultural research and poverty. The review is backward-looking in the sense that it examines the impact of past agricultural research based on available evidence. It traces the complex linkages between research and poverty, discusses conditions under which technological advancement helps or harms poor people, and suggests some approaches for promoting more favorable outcomes in the future. The focus is primarily on the relationship between improved agricultural technology—the outcome of research—and poverty; the relationship between the process of generating new technology and its poverty impact receives less attention.

The review is not intended to be exhaustive. Due to the nature of the available literature, the discussion of the impact of research focuses mainly on modern varieties of basic cereals. These improved cultivars receive the bulk of the attention in the impact analysis literature (Alston et al. 1998), partly because it is easier to trace their impact than it is for other research outputs (Anderson 1997). They are also the most important research outputs for poor people, whose diets and incomes depend greatly on them (Byerlee 1996), and they are the best-known outputs of agricultural research. Other kinds of research outputs are given much less attention.

Except when stated otherwise, the review focuses on publicly-funded research. Private agricultural research is also important to developing countries, and its role is growing with increased agricultural commercialization. However, most agricultural research in developing countries is supported by public funds, and this research more explicitly focuses on helping poor people. The CGIAR's mission, for example, is to contribute to food security and poverty eradication countries through research, partnership, capacity building and policy support.

The review suffers from a bias toward literature from Asia. This reflects both the authors' greater familiarity with literature from Asia than elsewhere and the simple fact that agricultural research has had its greatest impacts in Asia. The green revolution of the late 1960s was concentrated in south and Southeast Asia, and technical progress there has remained steady since then. This experience spawned a great deal of literature on technological advancement and social change in developing country agriculture.

Finally, this review is written for multiple audiences, including researchers, administrators, practitioners, donors, and the interested lay person. In attempting to address each group's interests it runs the risk of satisfying none of them. Readers may want to skim or skip sections with which they are already very familiar.

CRITICAL ANALYTICAL ISSUES

Two underlying analytical issues predominate in this review: the difficulties of measuring the impact of agricultural research on poverty alleviation and the design of strategies to ensure that the poor gain from agricultural research. Grappling with these issues is central to the review because the impact of agricultural research on poverty alleviation is both indirect and partial. Poverty has numerous determinants, some of which may be at least as important if not more important than agricultural research. This complicates efforts to understand the relationship between poverty alleviation and agricultural research and to design ways to make agricultural research more effective in helping poor people.

MEASUREMENT DIFFICULTIES

The effect of agricultural research on poverty comes through its effects on agricultural productivity. Research produces new technologies and management practices that increase productivity. Measuring the effects of research outputs on agricultural productivity is complicated enough, but measuring those on poverty is even more difficult. In the words of Anderson (1997), "We need to be quite humble about the actual possibilities of assessing "research impact holistically and to be modestly realistic when considering what information may turn up through any such formal assessment—which is not to say that we should not endeavor to do so!" Anderson points out the difficulty of precisely attributing the relative contributions to different components of the research and development process, and the role of factors other than research. He suggests that while improved cultivars are the easiest research outputs to assess, even they are complicated because modern varieties typically contain combinations of genetic material derived from several sources, each of which is the outcome of a separate research process. For other research outputs, such as management practices and human capital increments (e.g. through training and collaboration), it may be impossible to trace the links between the "production" of these outputs and changes in either productivity or poverty. Too many of the relationships are not measurable, and too many are indirect.

A closely related measurement problem is that technical change resulting from agricultural research takes place under the confluence of political, social and economic factors. In short, while improved agricultural technology may be critical to achieving the goals of economic growth and reduced poverty, it cannot do so by itself (Pinstrup-Andersen and Hazell 1985; Freebairn 1995). The initial distribution of income, the degree of equity in access to natural resources, markets and government services, and the nature of economic policies and institutions all combine to determine whether specific types of technological change will either help or hinder poor producers and/or laborers. Identifying the roles of all these factors is critical to understanding the relationship between agricultural research and poverty, but measuring the contribution of each is very difficult.

DESIGNING STRATEGIES TO MAKE AGRICULTURAL RESEARCH PRO-POOR

The complexity of the relationship between agricultural research and poverty alleviation makes it similarly complicated to design strategies to improve agricultural research's poverty alleviation impact. Possible approaches involve several components, although clearly there is no consensus about which ones to pursue. Broadly speaking, possible approaches include the following:

- designing social and economic institutions to give poor people equal access to information, land, capital, and markets for inputs and outputs
- ensuring that economic policies do not discriminate against economic sectors or regions with a disproportionate number of poor people, or against poor people within a given sector
- designing agricultural research and extension systems in ways that avoid biases against poor people
- biasing technologies, institutions and policies specifically in favor of poor people.

Whereas the first three items on this list emphasize neutrality between the rich and poor and equal access for all, the fourth specifically introduces a pro-poor bias. Controversies surround all four of these approaches. Regarding the first three, no one objects to them in principle, but in practice they may be difficult to achieve. Economists and other policy analysts may be able to conceptualize scale- and poverty-neutral institutions and policies that offer equal access to all, but in practice, social and political realities mean that designing and implementing them would take a long time if it were even possible.[1] In other words, aiming for neutrality between rich and poor may be inadequate because it may be unrealistic. The fourth approach of targeting research toward poor people's interests receives a different kind of criticism, which is that biasing technologies, institutions and policies specifically in favor of poor people may involve tradeoffs with economic growth that could slow poverty alleviation efforts over time (Alston et al. 1995). These potential tradeoffs need to be understood and evaluated.

It is important to distinguish between cases in which technical change is unnecessarily biased against poor people from the underlying fact that economic growth inevitably causes structural changes in an economy. Under economic growth, some sectors may expand while others contract; declining profits and employment in some sectors may be outweighed by rising profits and employment in the overall economy. The key challenges when this happens are to help people in declining sectors move to expanding sectors and provide them with safety nets to withstand difficulties in adjusting. This is no different from the problems facing American workers as employment falls in agriculture and in "rust belt" industries.

STRUCTURE OF THE REVIEW

This review is organized as follows. Following this introduction, it is divided into three parts: I) setting the stage (background), II) tracing the links between agricultural research and poverty alleviation, and III) issues for the future.

Part I contains Chapters 2-3. Chapter 2 defines poverty and poverty alleviation and addresses the issue of identifying poor people. Identifying the poor is important because agricultural research and technical change can have a variety of impacts that vary in their effects on different groups. For example, are poor people primarily urban or rural? Small farmers or laborers? Consumers or producers? Do they share several of these characteristics simultaneously? Do their attributes vary by continent, country or region? What other features, such as educational or health status and relative (lack of) economic power or political influence, describe poor people? Answering these questions will be critical to identifying potential impacts of agricultural research and technology development on poverty alleviation and designing strategies to strengthen them.

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[1] This explains why the moniker "the dismal science" should have been assigned to political science, not economics! Clearly, economics is the (perhaps overly) optimistic science.

Chapter 3 describes the products and achievements of agricultural research. This sets the stage for discussing how the impacts of research on poverty may vary by the type of research products or outputs. The major research output is production technology, but this may include either specific material inputs (such as modern varieties) or recommendations about how to combine resources for improved crop management. Agricultural research can also be social science-based, addressing how agricultural production systems fit into existing social, political or economic conditions. Social science research may shed light on how the design of a particular agricultural technology will affect its adoption, or set priorities for the focus of research, or help guide the design of policies to support particular agricultural development objectives. While this paper focuses mainly on research to develop production technologies, it also briefly addresses the implications for poverty alleviation of other kinds of agricultural research.

Part II (Chapters 4-8) reviews the past performance of agricultural research in alleviating poverty. Chapter 4 begins with a brief conceptual framework to link agricultural research and poverty alleviation. Two competing views are offered about the relationship between research and poverty. An optimistic view traces how research helps poor people through the following four mechanisms:

- raising farmers' production income
- generating agricultural employment with higher wages
- reducing food prices and providing greater food accessibility
- stimulating economic growth through linkages to the nonagricultural economy.

The nonagricultural economy in turn generates additional employment that further benefits the poor. The result is higher incomes and a sustainable food system.

The alternate view suggests that technical change is biased towards wealthy farmers at the expense of the poor, that it displaces laborers and damages their health, that it degrades the natural resource base, and that benefits from lower food prices benefit middlemen rather than consumers. The outcome according to this scenario is grinding poverty, social unrest and a food system that is politically and ecologically unsustainable.

Chapters 5-8 provide evidence from the literature to identify the conditions under which more productive agricultural technology will or will not lead to poverty alleviation through each of the four mechanisms mentioned above in the context of Chapter 4. Chapter 5 examines the effects of agricultural technology on producer incomes, Chapter 6 on wage incomes, Chapter 7 on consumers' food prices, and Chapter 8 on economic growth linkages and poverty alleviation. Many rural households work both as farmers and wage laborers, and they both produce and purchase food. As a result, changes in production technology, labor demand, and food prices can have complex, ambiguous effects on their welfare. These situations are discussed.

The literature on these topics was covered exhaustively by Lipton with Longhurst (1989), so the present paper draws both on their findings and those from subsequent literature. The bulk of the discussion focuses on the critical importance of policies and social institutions in determining the scale neutrality or bias of new technologies.

In Part III, Chapters 9-12 address some issues for the future. Chapter 9 addresses possible tradeoffs involved in biasing agricultural research towards poverty alleviation, presents some possible approaches to target research to the poor, and discusses some implications for the organization of agricultural research. Chapter 10 goes into some detail on approaches to promoting people's participation in community organization and agricultural research. Participatory approaches may be an important means of helping make agricultural research more effective in complex environments as well as empowering local people to influence the research system and learn problem-solving skills. Chapter 11 introduces two specific new technological advances, biotechnology and precision agriculture, and briefly discusses their implications for poverty alleviation. Finally, Chapter 12 discusses research methods for analyzing the impacts of agricultural research on poverty alleviation, either ex post or ex ante. It introduces impact assessment analysis, presents specific approaches to conducting such research, and discusses the complementarities of quantitative and qualitative methods.

Part I. Setting the Stage

Part I (Chapters 2 and 3) provides background information needed for discussion of the impact of agricultural research on poverty alleviation. Chapter 2 identifies the poor people who are among the clients of international agricultural research, and it introduces the nature and scope of the poverty alleviation problems. Chapter 3 introduces the activities and objectives of agricultural research and presents some of its achievements in generating new agricultural technology. It also discusses the poverty alleviation implications of some characteristics of agricultural technologies. Broader economic and social factors that determine the effects of technology on poverty alleviation are addressed in Part II.

2. IDENTIFYING THE POOR

Poverty can be characterized in numerous ways, ranging from traditional approaches that emphasize low consumption or income, to broader conceptions of well-being or livelihood. In recent years researchers have made progress in broadening the understanding of poverty in important ways and demonstrating some shortcomings of narrow measures based on consumption or income (UNDP 1998). Despite these new developments, this review is limited to using the traditional definition of poverty as material deprivation. The information reviewed focuses on quantifiable aspects of poverty. The main reason for this is that the international agricultural research system was mandated to alleviate poverty defined in terms of monetary and physical well-being, so its performance should be evaluated on the basis of these criteria. In any case, income and consumption are important components of well-being, and they are highly correlated to many other aspects of well-being (Carvalho and White 1997).

Despite this review's focus on measurable aspects of poverty, this chapter does present a summary of different perspectives in examining poverty. Among the concepts increasingly used to characterize poverty and poverty alleviation are well-being, livelihoods, vulnerability, social exclusion and empowerment. These are discussed in the appendix to this chapter.

MEASURING POVERTY AND IDENTIFYING THE POOR

When measuring poverty in traditional terms, typically people are considered poor if their standard of living falls below the poverty line. Two poverty lines are often used, an upper poverty line and a lower poverty line. The upper poverty line is defined in relative terms, typically a fraction of the median household consumption or income in the relevant geographical unit. The lower poverty line is based on the cost of a diet that provides minimal nutrition requirements and a very small allowance for nonfood expenditures. The lower poverty line is often referred to as the "one US dollar per person per day" poverty line. For both poverty lines, consumption standards are usually preferred over income standards for measuring poverty because, among other reasons, consumption is more stable from year to year (Carvalho and White 1997). Conventions

Box 2.1. UNDP Human Development Index

In response to concerns that poverty classifications based on per capita income are too narrow, in the past decade the UNDP has analyzed human well-being through its focus on "human development," defined as a process of enlarging people's choices (UNDP 1998). This is achieved primarily by "expanding human capabilities to lead long and healthy lives, be knowledgeable, and have access to the resources needed for a decent standard of living." These basic capabilities ensure a set of minimum choices available to people. More advanced but still essential choices range from "political, economic and social opportunities for being creative and productive to enjoying self-respect, empowerment and a sense of belonging to a community." The UNDP has developed a series of indices of human well-being (UNDP 1998). The Human Development Index (HDI), for example, measures overall achievements in three basic dimensions of well-being, including longevity, education and standard of living. The Human Poverty Index (HPI), meanwhile, captures the distribution of progress or lack thereof along these same three dimensions. While the HDI tracks standard of living in terms of per capita income, the HPI tracks the percentage of people without access to water and health services, and the percentage of children under five who are underweight. The Gender-related Development Index compares HDI performance between men and women, and the Gender Empowerment Measure incorporates gender inequality in economic and political participation and decision-making. None of these measures of well-being are meant to be comprehensive, but they help draw attention to the issues.

for selecting the level of income or consumption chosen to represent the upper poverty line often vary from one society to another. Poverty or deprivation is relative as human beings are social animals, and poverty is a socially determined state in the sense that it is what a society chooses to recognize and take measures to help overcome (Sen 1980; Ruggles 1990). Ravallion (1994) provides a critical overview of ways to measure poverty, compare poverty levels across contexts, and specify poverty lines.

POVERTY DATA SETS ARE WEAK

Global information on the extent and severity of material poverty is limited. Data availability for different countries varies and the standards used are different. Poverty standards used in Latin America are close to US$ 1 per person per day but in Central Asia they are close to $4 in Central Asia; China uses a standard of about US$ 0.60 per person per day. The World Bank uses the dollar per day standard mentioned above to compare poverty across countries and regions. The estimates of poverty are sensitive to poverty standards, and of course millions of poor people with incomes slightly above this very low standard of living are not counted.

HOW MANY PEOPLE ARE POOR, AND WHERE DO THEY LIVE?

Using the World Bank standard for extreme poverty of $1/day/person, 29 percent of the world′s poor or 1.6 billion people were considered extremely poor in 1993. There was a small reduction in the percentage of people in extreme poverty from 30 to 29 percent between 1987 and 1993, but thanks to global population growth (from 5 to 5.5 billion) the absolute number of extremely poor people rose by about 100 million (FAO 1999). Likewise, in India the percentage of poor people declined from 55 to 43 from 1970 to 1987, but with population growth the total number of poor people grew by 36 million. The tremendous impact of population growth demonstrates the difficulty of reducing the number of people in poverty. Lipton and van der Gaag (1993) point out that the majority of new births today are in the poorest and least educated households of the poorest countries. Not only does this make it difficult to reduce the number of people in poverty, but it also swells the ranks of unskilled workers who need employment.

Table 2.1 shows the percentage of people living in poverty in different regions between 1987 and 1990. Sub-Saharan Africa and South Asia had about the same percentage of people in poverty in 1985, but due to its much larger population, the absolute number of poor people was more than twice as large in South Asia. Almost half of the world’s extremely poor people live in South Asia, of whom over three quarters are in India alone. The poverty gap, that is the distance between the average poor person’s consumption and the poverty line expressed as a percent of the poverty line, was higher in South Asia and Sub-Saharan Africa compared to other regions. The gap was 12.6 percent in South Asia and 15.3 percent in Sub-Saharan Africa compared to 9.1 percent in Latin America and Caribbean and 7.8 percent in East Asia and Pacific (World Bank 1998). The percentage of people in poverty declined in East Asia, the Middle East and North Africa, and South Asia. It rose slightly in Latin America and Sub-Saharan Africa. If current trends continue, Africa could have as many poor people as India within a few decades.

Table 2.1: Changes in poverty levels, 1987-93

	Number of poor people (millions)		Share of population (%)		Poverty gap (%)
Region	1987	1993	1987	1993	1993
East Asia and Pacific	464.0	445.8	28.8	26.0	7.8
Europe and Central Asia	2.2	14.5	0.6	3.5	1.1
Latin America and Caribbean	91.2	109.6	22.0	23.5	9.1
Middle East and North Africa	10.3	10.7	4.7	4.1	0.6
South Asia	479.9	514.7	45.4	43.1	12.6
Sub-Saharan Africa	179.6	218.6	38.5	39.1	15.3
Total	1,227.1	1,313.9	30.1	29.4	9.2

Source: World Bank (1996)

Although poverty is more concentrated in rural areas, it is gradually shifting to urban areas along with the relocation of population (Table 2.2) (Haddad et al. 1999; Naylor and Falcon 1995). The world's rural population is projected to increase only marginally from 3.2 billion to 3.3 billion between 2000 and 2025 while the urban population is projected to increase from 2.9 to 4.7 billion (United Nations 1998). Rural population is in fact projected to decline absolutely in Latin America and the Caribbean and in Asia. Urban poverty rates are lower than rural, but urbanization will cause the number of urban poor to increase unless urban poverty incidence is reduced sharply.

Table 2.2: Percentage of population living in urban areas by region, 1961-1997

Region/Country	Year		
	1961	1981	1997
China	16	20	32
Southeast Asia	17	24	35
South Asia	17	22	27
Sub-Saharan Africa	12	22	33
Latin America	50	66	74

Source: FAO 1999

Haddad et al. (1999) examined urban and rural poverty in eight countries that account for nearly two-thirds of the people in the developing world. In five of the eight countries, the absolute number of urban poor and the share of poor people living in urban areas is increasing over time. The absolute number of underweight children in urban areas is also increasing at a rate faster than in rural areas. For a majority of countries, they found growth in urban poverty in terms of both the number of people below the poverty line and the number of underweight preschoolers.

Alleviating urban poverty may require strategies different from those for rural poverty. Urban life differs from rural life in that people cannot produce their own food, environmental hazards change from natural hazards to industrial pollution, infrastructure is better, and social life is much more fragmented (Moser 1998; Satterthwaite 1997). These differences create both advantages and disadvantages in designing poverty alleviation strategies.

Examining poverty rates and trends by region reveals some interesting differences and similarities.

ASIA

Asia contains the bulk of the world's poor, as mentioned above. While South Asia has the poorest people with between 40 and 50 percent of the world's total, a third of the world's poor live in East and Southeast Asia, mostly in China and Indochina. Many countries in the region have shown a dramatic decrease in poverty over the past few decades, although the recent economic crisis raised the numbers again. The percentage of people living on less than one dollar per day fell from 60 to 20 between the mid-1970s and mid-1990s (World Bank 1998).

Poverty in Asia is mostly rural. In Vietnam, the incidence of poverty is 57 percent in rural areas compared to 27 percent in urban areas (World Bank 1998). The most vulnerable groups of rural poor in Asia are tribal and ethnic populations, and rural poor women. Landless households make up nearly one quarter of the population and smallholders nearly one half; together these groups have the largest numbers of poor people.

India has particularly good published data on long-term poverty trends. Table 2.3 shows that despite good progress in reducing the percentage of people below the poverty line in the 1970s and 1980s, the absolute number continued to grow. Poverty remains more concentrated in rural areas.

Table 2.3: Poverty estimates for India, 1970-1987: percentage of population and absolute number

Segment of population	1970-71		1983-84		1987-88	
	Percent	Number	Percent	Number	Percent	Number
Rural	57	252	49	267	45	261
Urban	46	50	38	66	37	75
Total	55	302	46	333	43	336

Source: Minhas et al. (1991)

SUB-SAHARAN AFRICA

The incidence of poverty in this region, which contains some of the poorest countries in the world, remained at around 39 percent from 1987 to 1993 according to Table 2.1. As in Asia, most of the population and a disproportionate number of the poor are in rural areas. Nigeria and Ghana, the two largest countries, account for nearly one fifth of the total population. In Sub-Saharan Africa, nearly 73 percent of the rural populations are smallholder farmers owning up to 3 hectares of cropland. The landless make up about 11 percent of the rural population and pastoralists about 13 percent. The number of households headed by women is the highest in the world at about a third of the total, and they are more likely to be poor than other households.

LATIN AMERICA AND THE CARIBBEAN

About a quarter of the population in this region lives on less than dollar a day. Income distribution in this region is the most unequal in the world. Countries in the region can be grouped in to three categories of rural poverty. The critical group in which more than 75 percent of the population is poor includes Haiti, Bolivia, Guatemala, Honduras, Nicaragua, El Salvador and the Dominican Republic. The high incidence group in which 50-75 percent of the population is poor includes Brazil, Mexico, Peru, Panama, Colombia, Ecuador, Paraguay, Venezuela, and Chile. The last groups, with less than half of the people are poor, include Argentina, Costa Rica, Uruguay and Cuba. Because of the large population base and fairly high levels of poverty, Brazil has the largest population of poor people in this region.

Latin America and the Caribbean have largely urban populations and most of the poor are urban as well. 74 percent of the population lives in cities areas compared to 38 percent in the developing world as a whole. Large portions of the urban poor are single mothers and young people. The poorest 10 to 20 percent of the population, however, are still in rural areas. They are mostly indigenous people in remote areas with low agricultural productivity and few nonfarm jobs. As in other regions, the most vulnerable groups are the smallholder farmers, rural landless, indigenous populations and households headed by women.

According to ECLAC, the percentage of destitute people in Latin America and the Caribbean actually rose from 19 to 21 percent in the 1980s. 24 million additional people suffered from extreme poverty. Urban poverty rates grew the fastest, with 44 percent of the increase coming in Brazilian cities alone (Landell-Mills 1996, pg 186).

APPENDIX: DEFINING POVERTY

Perceptions about poverty have changed considerably in recent years. Many researchers and development professionals have shifted their focus from what they can measure easily to aspects of poverty that are important to poor people themselves, and to understanding processes that contribute to poverty. It is generally accepted now that neither money income nor consumption can adequately capture welfare; "the concept of human poverty is much bigger than the measure" (UNDP 1998). Focusing on multidimensional concepts has improved understanding of poverty and the obstacles to providing sustainable livelihoods (Lipton and Maxwell 1992).

Well-being

Chambers (1997) argues that the objective of development is well-being for all, where well-being refers to a good quality of life. It is much broader than wealth and includes the whole range of human experience: social, mental and spiritual as well as material, and each individual may define it differently. Two basic components of well-being are having a secure livelihood to meet one's basic needs, and realizing and expanding one's capabilities in order to achieve fulfillment (Chambers 1997; Sen 1993).

Findings of the World Bank's participatory poverty assessments (PPAs), conducted in a number of countries, support the notion of well-being as the central objective of development. They indicate that poor people consider poverty to be about more than just income or consumption or health or education. They characterize poverty as ill-being, in terms of factors such as vulnerability, physical and social isolation, lack of security, lack of self-respect, powerlessness and lack of dignity (Robb 1999; Moore et al. 1998; Snyder 1995). Surveys by Jodha (1988) and Beck (1995) in India suggest the same. Inclusion of factors such as autonomy, self-esteem and participation in poverty definitions blur the distinctions between higher and lower level needs of human beings as some needs are expected to become important only after basic needs such as food, shelter and housing are met (Maxwell 1999).

Livelihoods

As originally defined by Chambers and Conway (1992), “A livelihood comprises the capabilities, assets and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stress and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base” (DFID 1998). Livelihood captures larger issues of sustainability by incorporating the status of natural resources in the definition, as their deterioration may undermine opportunities for the poor.

Under the livelihood approach, alleviating poverty focuses on building poor people’s capital assets, which include natural capital, physical capital, social capital, human capital and financial capital (DFID 1998). Natural capital includes natural resources such as land, livestock, trees, etc., physical capital includes man-made structures and objects, financial capital includes cash and financial investments, human capital includes a person’s mental and physical skills, and social capital includes social relationships. The major assumption in livelihood strategies is that there is a close relationship between overall asset status and robustness of livelihoods. Natural and physical capital, for example, in addition to determining poverty status, are significantly associated with depth and severity of poverty, and the range of escape strategies available to poor (Cox et al. 1998).

Another way to classify assets is as productive assets, stores and claims. Productive assets can generate income; examples include land, livestock, and human capital. Stores are material assets that can be consumed or sold; they include such things as bank accounts, jewelry, food, clothes, or housing. Some assets, like land, may be considered as either a productive asset or a store. Claims are social assets; they are based on relationships with people who can provide help in a time of need. Claims may be based on friendship, kinship, business relationships or political power. They may involve friends, relatives, neighbors, patrons, organizations, governments or the international community. Households can build more secure livelihoods by investing in all three types of these assets.

Vulnerability

Vulnerability is a concept useful to understanding poverty's causes because it captures changes in processes leading to poverty (Moser 1998). Vulnerability refers to exposure to contingencies and stress and difficulty in coping with them (Chambers 1997). It gives an indication of an individual's or household's ability or inability to withstand shocks, i.e. to maintain an adequate consumption level despite adverse circumstances. Vulnerability represents the opposite of a secure and sustainable livelihood.

Vulnerability has two sides. The external side is risks, shocks and stresses to which an individual or household may be subjected to. The internal side is the means or lack of means to cope with damaging loss; it depends on assets available to meet contingencies. Assets create a buffer between production, exchange and consumption (Swift 1998). Individuals, households and communities mobilize assets and entitlements when they face hardships (Moser 1998), and loss of assets makes households and communities more vulnerable. Productive assets like human capital and land, stores like cash and food stocks, and social claims are all important sources of protection against vulnerability.

Social claims may play a particularly important role in reducing vulnerability for the poorest people who have few productive assets or stores. Being part of a solidarity network, for example, is an important source of claims for poor people that can keep them from having to lose status by begging for help during difficult times. Using household membership in various groups as a proxy for household stock of social capital, (Maluccio et al. 1999) found a positive and significant impact of social household relations on per capita total expenditure in South Africa. The poor are becoming vulnerable in some regions because of declining patron-client obligations and support from joint families (Chambers 1998).

Political power can also reduce vulnerability because it can form the basis of socially enforceable claims (Gasper 1993). Inability to influence political processes may weaken the claims of socially marginal groups, making them unable to influence resource allocations. In many African countries it may deny them food entitlements (Watts 1991).

In parts of India, the poor have to negotiate and protest to protect their access to village common properties, which are an important source of income (Beck 1995).

Uncertainty of income is another source of vulnerability. Reduction in uncertainty, even without any change in long-term economic and financial assets, may raise well-being (Cox et al. 1998) by reducing the risk of critical shortfalls in consumption.

Social exclusion

The concept of social exclusion focuses on the institutional processes that lead to deprivation (de Haan and Maxwell 1998). It is defined as the "process through which individuals or groups are wholly or partially excluded from full participation in the society in which they live" (European Foundation 1995). Multiple types of deprivation, characterized by low income, insecure employment, poor housing, family stress and social alienation, are also a defining feature of social exclusion. Social exclusion can be seen either as a process or an outcome. As an outcome it generally results in relatively lower incomes and failure or inability to participate in social and political activities (de Haan and Maxwell 1998). Participation therefore becomes essential for those excluded to address their problems.

Empowerment

Empowerment is a term that different people use to mean different things. In this review it refers to a development strategy that addresses some of the key dimensions of poverty highlighted by conceptualizations that go beyond material deprivation. Empowerment approaches aim to enhance capabilities of people to participate in development processes. It has its roots in participatory action research, an underlying principle of which is that making people aware of problems can make them willing to act to solve them (Freedman 1997). Empowerment strategies have the potential to create demand for changes from the least well-off, and also greater willingness and ability among them to participate in change processes.

Empowerment as a process involves changing power relations. One aspect of power is individual capabilities. People feel they have power when they can adequately cope with situations around them; this relates to their sense of self-worth and capability. Empowerment in this context involves giving people greater confidence in their own abilities or the '*power to*' do a number of things (Conger and Kanungo 1988; Nelson and Wright 1995). People have an intrinsic need for self-determination; PPAs suggest that people place high value on their self-respect and independence. Empowerment strengthens one's sense of self-worth and weakens one's belief in personal helplessness (Conger and Kanungo 1988).

Another aspect of power is the control that an individual or a group has over others. Empowerment in this context is giving people control or '*power over* processes that affect them (Nelson and Wright 1995). It aims to give the poor opportunities to participate in political, social and economic arenas rather than being passive recipients. The link between these two aspects of empowerment may be quite obvious. The poor who gain confidence in their own capabilities may demand or take advantage of opportunities to participate in various spheres. At the same time, their greater participation also enhances their sense of self worth.

Is empowerment relevant to agricultural research? How agricultural research systems operate has considerable implications for meeting the technology needs of poor farmers in unfavorable agroclimatic regions. Who decides research priorities and technology development approaches are two important aspects of how research systems operate. In most countries, resource-poor farmers in unfavorable regions are 'passive recipients' of technologies; they have control over the priorities of the research systems that serve them. The research process ignores farmers' knowledge and experience even though they may offer insights that could help develop effective technologies for unfavorable areas. Such systems may perpetuate a sense of helplessness among resource-poor farmers who wait in vain for effective technological solutions to come from outside. Participatory research, discussed in Chapter 10, offers an alternate approach based on empowerment. Participatory approaches aim to build farmers' own capability to innovate and give them greater influence over decisions in agricultural research.

INTEGRATING APPROACHES

Underlying the concepts of poverty related to “measurement” and “understanding” are qualitative and quantitative approaches to gathering and analyzing information. The conventional focus on measuring poverty relies on large-scale, rigid surveys and quantitative data analysis. A focus on understanding poverty from poor peoples’ perspectives gives greater weight to qualitative approaches, including participatory assessment. Recent expansion of interest in participatory research methods has helped stimulate the improvement in understanding poverty from poor people’s perspectives. Quantitative approaches, meanwhile, offer greater ease of measurability and comparability, and this helps explain why agencies such as the World Bank use income as their primary measure of poverty. The relative strengths and weaknesses of quantitative and qualitative data collection and analysis, along with suggestions to make them complementary to one another, are discussed in more detail in Chapter 12.

3. PRODUCTS AND ACHIEVEMENTS OF AGRICULTURAL RESEARCH

This chapter introduces agricultural research, describes its outputs and documents some of its achievements. It discusses briefly how characteristics of agricultural technologies have inherently different potential effects on poor and nonpoor people. However, poverty impacts of new technology cannot be assessed independently of the socioeconomic and policy environment, and discussion of the latter is postponed until Chapters 5-8.

CATEGORIES OF AGRICULTURAL RESEARCH OUTPUTS

As mentioned above in Chapter 1, agricultural research yields a variety of types of output that vary in their objectives and potential impacts. This chapter introduces several types of research outputs, including material inputs such as improved cultivars, plant protection chemicals, machines, agronomic practices for improved crop management, and social science research output, which includes identification and understanding of the social, institutional and policy context of technical innovation as well as the management of the research process. The best-known form of agricultural research is the development of modern varieties; this kind of research has received the lion's share of attention in the literature on research impact (Alston et al. 1998). Accordingly, modern varieties are the main focus of this review. In fact, except when otherwise mentioned, the discussion refers to modern varieties.[2]

[2] The CGIAR's research budget is divided approximately as follows: breeding and germplasm enhancement: 20 percent, production systems development and management: 20 percent, policy improvement: 11 percent, saving biodiversity: 11 percent, strengthening national agricultural research systems (NARSs): 21 percent, protecting the environment: 17 percent. Of this, "saving biodiversity" refers mainly to maintaining seed banks that contribute raw materials for breeding, and strengthening NARSs cuts across several research areas including plant breeding (CGIAR Secretariat, World Bank, Washington).

IMPROVED CULTIVARS

Improved genetic material embodied in seeds is the most fundamental and perhaps most familiar type of agricultural research output. “Improved” may refer to any of several desirable characteristics: higher potential grain yield, responsiveness to other inputs such as fertilizer and/or irrigation, greater tolerance to stresses such as droughts, pests or diseases, a shorter duration (length of growing season), longer storage capability after harvest, higher nutrient content, better taste, higher fodder quantity or quality, etc. In practice, most research on modern varieties has focused on raising yields, reducing susceptibility to various stresses, and reducing duration (length of growing season). Typically the research focus is determined by crop scientists, with varying degrees of input from social science researchers, extension workers and other field workers, and farmers.

All of the traits listed here can be favorable for rich and poor farmers alike, and modern varieties that raise production also raise demand for labor to carry out productivity-enhancing agronomic practices and harvest the larger crop. Differential effects on poor and nonpoor farmers depend on the importance of cash inputs and farmers’ access to them. Varieties that respond to cash-intensive inputs such as fertilizer (described below) may be less beneficial for poor, cash-constrained farmers. Similarly, many modern varieties will offer high productivity only in regions with favorable agroclimatic conditions, so only farmers in those regions will benefit. This creates a bias against farmers in unfavorable areas, which are often particularly impoverished.

Improved cultivars also vary by the scientific approach to plant breeding. Traditionally the choice was between open-pollinated varieties and hybrids, and in recent years biotechnology has provided new alternatives. Under open pollination, harvested seeds can be replanted year after year without any loss of productivity. Hybrids achieve yield gains by combining two inbred seed populations. Hybrids’ offspring can be replanted, but their productivity will fall steeply over time. Maintaining high productivity requires that farmers repurchase parent stock seed every year from the supplier. This makes hybrids attractive to private suppliers, whereas open-pollinated varieties are of greater interest to the public sector.

Biotechnology has been applied to both hybrids and open-pollinated varieties and enables two kinds of breeding advances. First, it speeds up the process of combining plant characteristics in conventional breeding, and second, it enables incorporation of genes drawn from an unrelated plant species. Biotechnology is discussed in more detail in Chapter 9.

OTHER MATERIAL INPUTS FOR CROP PRODUCTION

Other material inputs besides cultivars include chemical inputs such as fertilizers, herbicides, pesticides, and mechanical equipment.

Chemical inputs provide a substitute for organic inputs or human labor. Fertilizer, for example, provides nutrients that could also be supplied by applications of organic matter, and herbicides kill weeds that would otherwise have to be pulled by human workers, animal power or machines. Pesticides are used to kill mainly insect pests that would otherwise consume standing crops in the field, but they also kill those pests' natural enemies. Pesticides replace management techniques that include, among other things, planting a mix of crops to reduce susceptibility to a particular pest and encouraging pests' natural enemies. By definition, pesticides are highly toxic and will sicken or even kill users who do not use them properly or are overexposed to them (Loevinsohn 1987; Pingali and Rola 1993).

Farmers who wish to use any of these chemical inputs must purchase them from commercial suppliers. Unlike with open-pollinated varieties, private sector producers have a strong incentive to conduct research on these inputs because they can capture the full market value of returns to their investment. Not surprisingly, the private sector conducts nearly all of the global research on development of chemical inputs.

Agricultural machines also substitute for human workers and animal power. One important point about agricultural machines is that they do not necessarily raise output relative to alternatives such as human labor and/or animal traction. According to a famous study by Binswanger (1978), tractors in South Asia were found to affect the cost of agricultural operations but not their effectiveness or productivity. As a result, from an economic perspective their use is justified only when they are less costly to use than labor or animal traction.

Another important feature of agricultural machines is their *indivisibility*. Compared to seeds or chemical inputs that farmers can purchase in roughly the exact amount they need to use at any given time, machines are an “all-or-nothing” investment. This can give larger farms an advantage over smaller farms in using them by reducing the cost per hectare on a larger farm. However, machinery rental markets can reduce or eliminate the indivisible nature of agricultural machines. Rental markets typically work well where dense population enables each machine to have many users, and where timeliness of operations is somewhat flexible, so that all potential users do not need the machine at the same time.

CROP MANAGEMENT PRACTICES

Agronomic or crop management research may account for half of all crop research (Traxler and Byerlee 1992). It aims to develop new techniques to manage natural resources and material inputs in a way that raises production. This can involve identifying optimal combinations and quantities of inputs or developing better management practices that do not involve material inputs, such as improved timing of operations and crop rotations. Integrated pest management, whereby insect pests are managed through such techniques as crop rotations and encouraging natural predators, can be categorized as a crop management practice. Implications for who conducts crop management research and whether its benefits are scale-biased depends in part on whether it involves purchased inputs and how the research results are made available to potential users.

Trees

Trees are another area for agricultural research. Farmers in humid and semi-humid tropical areas grow large numbers of trees bearing fruit, spices, fuel, medicines, timber and a variety of other products. Some nitrogen-fixing trees, grown alongside field crops, serve as green manure to increase soil fertility. Tree researchers search for disease resistance, optimal intercrops, and fruit bearing in off-seasons.

Livestock

Livestock are an important component of farming systems throughout the developing world. The most important areas for research on livestock are improving animal health and nutrition and developing market systems for both livestock inputs (feeds, medicines, veterinary services, artificial insemination) and outputs (milk and meat products). Although both livestock and trees are very important, this paper focuses primarily on food crop research.

Socioeconomic information and policy analysis

Social science information is an important category of research output. It encompasses at least three types of analysis: 1) identifying socioeconomic conditions, including policies and social institutions, that may determine demand for or constraints to adoption of different technologies, 2) setting priorities for allocating research resources, and 3) developing mechanisms to help poor people gain access to inexpensive food without undermining incentives for farmers to maintain high productivity. The first two of these are closely related to the role of research in developing agricultural technology that contributes to increased food production, economic growth and poverty alleviation. Typically such research is carried out by the public sector, though the private sector may have an incentive to conduct some market research to identify sales opportunities. There is no inherent scale bias in socioeconomic research; in fact it may be organized around the objective of identifying ways to skew benefits to poor people. The third type of socioeconomic research listed here does exactly that.

Box 3.1. Environmental problems associated with the green revolution

Agriculture has always required that humans manipulate the natural environment to fulfill their own objectives. The green revolution represented a modern variation of this relationship, with substantially greater environmental manipulation. Early green revolution varieties of rice and wheat reflected this new approach and its associated challenges. The new varieties had several disadvantages, including a narrow genetic base, high cash requirements, and reliance on the use of chemical inputs. Their introduction reflected, in part, the belief that their high yielding capability in a time of growing food scarcity outweighed these disadvantages. It is also likely that some problems with the technologies were not anticipated in advance, or that scientists figured they could solve those problems as they arose.

The first high yielding rice variety widely distributed in Asia was highly susceptible to pests. Heavy pesticide applications poisoned farmers, killed natural insect predators and led to the evolution of new, pesticide-resistant insect strains. With the introduction of new pest- and disease-resistant varieties, new, previously unknown pathogens emerged to pose new problems. As a result, plant scientists must continually develop new sources of resistance to new plant enemies.

Green revolution rice and wheat both required fertilizer to realize higher grain yields. At the same time, farmers in Punjab adopted a rice-wheat cropping system that replaced traditional crop rotations that included soil nutrient-replenishing legume crops. The rice-wheat system would lead to nutrient depletion without the addition of large nutrient inputs. Short-statured rice and wheat produced less biomass, so less was available to be plowed into the soil or to feed to livestock. Manure was expensive relative to chemical fertilizer, so farmers relied increasingly on chemical fertilizer to maintain nutrient levels. After two decades of this management system, signs of declining productivity emerged, as higher fertilizer applications were needed just to maintain yields. Many high yielding varieties are also highly water intensive, and because their short duration enabled multiple cropping, the overall demand for water rises even more. In India, the first green revolution wheat variety consumed three times as much irrigation water per hectare as previously used varieties. Poor irrigation management led to salinity and drainage problems that rendered large tracts of land unproductive, requiring major investments in reclamation. Farmers in some areas invested in costly irrigation pumps to extract groundwater, but poor people faced difficulties in accessing this technology.

Source: Shiva (1991)

ACCOMPLISHMENTS OF AGRICULTURAL RESEARCH

Modern varieties are the chief research output discussed in this paper because they are easy to conceptualize, their impact has been undeniable, and there is a great deal of literature about them.

The Green Revolution

The green revolution refers to the introduction of semi-dwarf varieties of rice and wheat in the mid-1960s. Known as the “miracle grains,” these high yielding varieties transferred genetic growth potential from the plant’s straw to its grain output, thus raising yields greatly. Improved grains were the direct result of two independent agricultural research programs: one initially funded by the Rockefeller Foundation in the 1940s, and another by the Chinese national agricultural research system (Herdt 1997). The Rockefeller Foundation's work resulted in the production of new wheat varieties in Mexico and stimulated the founding of the International Rice Research Institute (IRRI) in the Philippines and CIMMYT in Mexico in the early 1960s. These various agricultural research initiatives all contributed to the improvements in open-pollinated varieties that led to the green revolution.

The early green revolution cultivars were highly responsive to fertilizer, which they converted efficiently into increased grain output whereas traditional varieties could not do so. They also responded well to irrigation, in part because fertilizer performs better with regular watering. IRRI's rice varieties were highly susceptible to pest attack, so their yields were highest when sprayed with chemical pesticides. On the whole, the green revolution varieties were highly input-intensive

Post-Green Revolution

Descriptions of modern varieties often end with the description of the green revolution due to two critical misunderstandings regarding the role of modern varieties inaising agricultural yields (Byerlee 1996). First, varietal improvement was not a one-time event under the green revolution. The early new varieties played a great role in raising crop yields, but they also raised new challenges for scientists to address; since then continued incremental breeding improvements have stimulated steady output and yield growth. Second, post-green revolution advances in plant breeding have greatly raised the scope for continuing to increase yields without similarly increasing the use of chemical inputs.

Byerlee (1996) makes several points worth noting:

- Whereas the 1960s green revolution in wheat was based on only two semi-dwarf varieties, the Indian NARS now releases an average of 8 varieties each year. Most farmers have replaced their varieties at least twice since the original adoption of the first modern varieties. For developing countries as a whole, second-generation modern varieties have contributed genetic yield gains of 0.5-1.5 percent annually. Varietal replacement and yield gain have followed similar patterns in rice. Rice’s genetic potential peaked in the early 1980s but since then, new varieties have incorporated tolerance to an increasing array of pests and diseases and other stresses. This enables farmers in a broader agroecological range to achieve higher yields.
- Green revolution varieties were not very resistant to pests and diseases, but neither were the traditional cultivars they replaced. In fact, resistance to the devastating disease leaf rust was a critical advantage of the early modern wheat varieties. Since the green revolution, plant breeders have worked with great success to increase pest and disease resistance. Figure 3.1 shows the gradual elimination of the yield gap between farms that apply chemical fungicides to fight disease and farms that rely on the wheat plant's inherent resistance. The green revolution rice varieties were resistant to only one kind of insect pest and required substantial chemical sprays to control others. Today's varieties, by comparison, are resistant to six or seven insect pests and no longer require pesticide application (Rola and Pingali 1993). (Pest-resistant varieties are also an important component of integrated pest management systems.) Reduced susceptibility to pests has made yields

of both rice and wheat far more stable than at the time of the green revolution.

- Whereas early green revolution varieties were concentrated on irrigated land, recent breeding improvements have enabled modern varieties to spread to rainfed areas. Figure 3.2 shows progress in this regard in Pakistan, Argentina and Syria. Figure 3.3 shows that in India, the area under modern varieties of all types of cereals (wheat, rice, maize, sorghum and millet) greatly exceeds the area irrigated. Byerlee estimates that in the 1980s, modern varieties spread to an additional 20 million hectares of cereal area in India, a figure comparable to adoption rates at the height of the green revolution. Whereas the green revolution was almost exclusively on irrigated land, three quarters of the more recent adoption took place on rainfed land and much of this was on semi-arid or even arid land.

Figure 3.1: Yield of historically important varieties (released 1964-86) treated and untreated with fungicide, Ciudad Obregon, Mexico, 1990-91

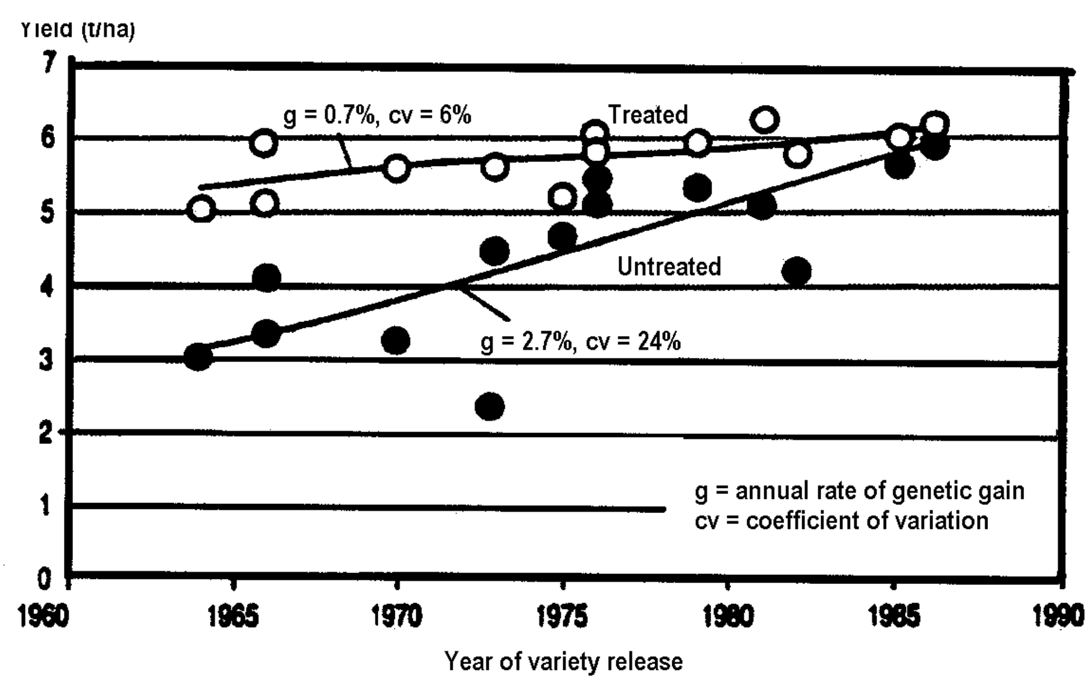
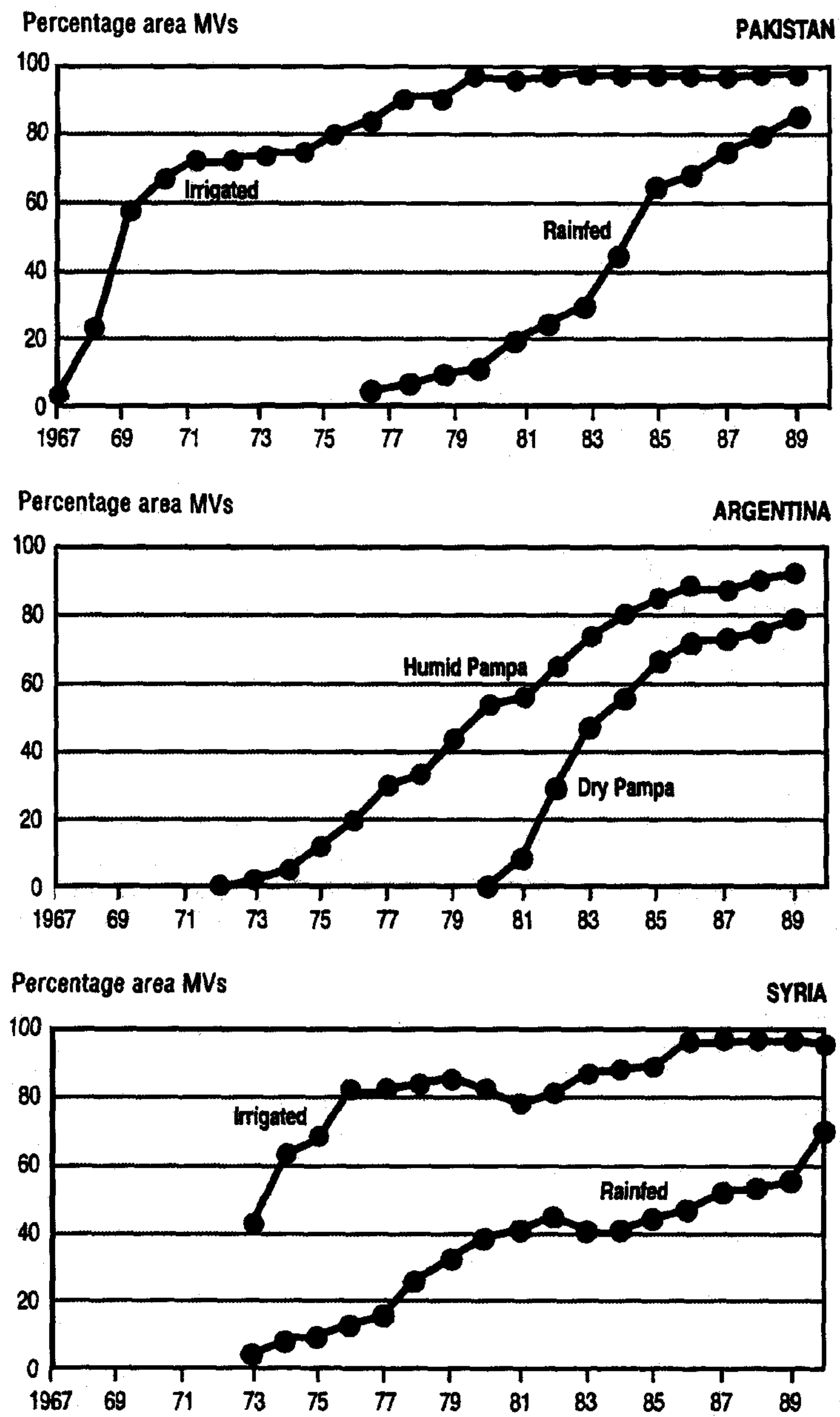
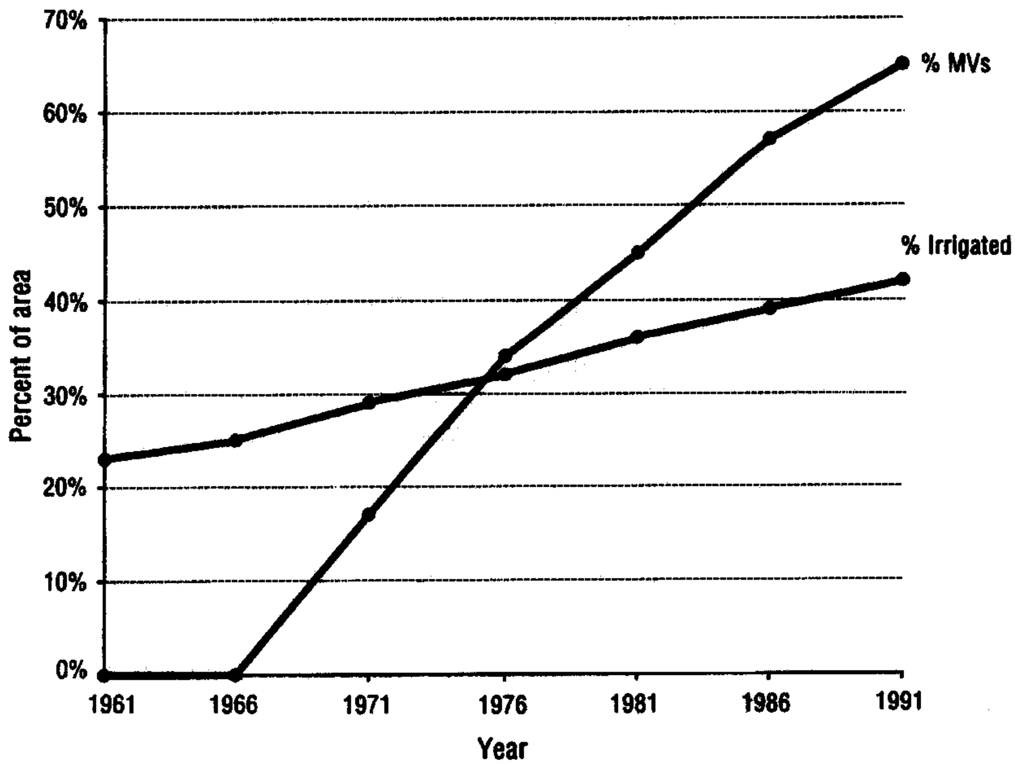


Figure 3.2: Adoption of modern spring wheat varieties in different moisture zones, 1967-89



Source: Byerlee and Moya (1993).

Figure 3.3: Percentage of cereal area irrigated and planted to modern varieties, India.



- Development of modern varieties with successively shorter duration (growing season) has enabled increasing numbers of farmers to adopt double and triple cropping. This has enabled additional food production increases that do not show up in yield data.
- The role of modern varieties in reducing genetic diversity in farmers' fields is greatly overstated. In irrigated areas of India and Pakistan, green revolution wheat varieties replaced one or two dominant local varieties that farmers had been planting since 1910 (Shiva 1991), so traditional systems enjoyed neither spatial nor temporal diversity. The same is true of the dominant traditional sorghum variety in much of India. Today's modern varieties offer three genetic diversity advantages: 1) they

contain genetic material from numerous sources, so each MV represents significant diversity; 2) they are more narrowly targeted to specific ecosystems, raising spatial diversity, and 3) they are replaced by completely new varieties with increasing frequency, thus raising temporal diversity. The spread of modern varieties into rainfed areas has increased the erosion of genetic diversity since this is where indigenous landraces are grown, but recent analysis has shown that landraces have surprisingly narrow diversity for some traits. New modern varieties are often more genetically diverse and have greater resistance to important pests and diseases (Byerlee cites M. Sorrell, personal communication).

- Breeding has been little used as a tool to improve soil nutrient management, but it may have some unexploited potential in this regard. It would be possible to breed varieties for increased nutrient uptake from the soil; the prospects are better for some nutrients than others. For nitrogen, it would be equivalent to nutrient mining and would deplete the soil within a few years unless farmers applied additional nitrogen. Alternately, breeding can raise fertilizer efficiency, which reduces the amount of fertilizer needed to achieve a given yield and reduces groundwater pollution because root systems reduce leaching of nitrates. CIMMYT's wheat breeders have made good progress in this regard; Figure 3.4 shows improvements in fertilizer efficiency for successive wheat releases.

Other recent research achievements include the following:

- Scientists at IRRI and in the Indian NARS have recently developed a hybrid rice plant suitable for tropical conditions that will yield 15-20 percent more grain than the best open-pollinated varieties. IRRI scientists are working on a new "super" rice variety with drastically altered plant architecture that will raise yields by 30 percent above existing open-pollinated varieties. Hybrids derived from the super rice varieties would raise yields yet another 20 percent. Widespread adoption of such plants in farmers' fields is probably 10-15 years away (Pingali et al. 1997)

- Researchers at ICRISAT have made great strides in improving pigeonpea, a pulse crop consumed by an estimated 1.1 billion people around the world. Pigeonpea is potentially an important source of protein in India, but its high cost constrains effective demand (Chung 1998). Research on this crop brought major diseases under control in large tracts of India, reducing crop production costs by 42 percent. More recently, short duration varieties have been developed that may find a niche the irrigated rice-wheat systems of the Indo-Gangetic plain. Short duration would enable farmers to grow the crop after the rice harvest without delaying wheat planting. As a nitrogen-fixing legume, pigeonpea would contribute to restoring soil nutrients (ICRISAT 1998).
- Among inferior grains consumed mainly by poor people, researchers at ICRISAT also developed a pearl millet variety with multiple sources of resistance to downy mildew, a major disease that causes severe losses. In Africa, after early difficulties ICRISAT has contributed to development of 23 improved millet varieties and 42 sorghum varieties (Oehmke and Crawford 1996; ICRISAT 1996).
- In Africa, improved open-pollinated maize varieties yield 15-25 percent more and hybrids over 30 percent more than traditional varieties. Adoption of these improved cultivars on more than 40 percent of cultivated area may account for over half of annual growth in African maize yields since 1970 (Byerlee and Eicher 1997). Three-quarters of maize varieties released in Africa by the 1980s derived at least in part from genetic material from international agricultural research centers (IARCs).

INCREASES IN OUTPUT RESULTING FROM RESEARCH-LED TECHNICAL CHANGE

The various advances listed above have translated into major production increases. Before the green revolution Asian agricultural output grew mainly through expansion of cropped area. By the mid-1960s, however, there was little scope to continue this path because the best lands were fully utilized. Modern varieties offered the alternative of raising yields so that more food could be produced on existing crop land. As new varieties spread and were improved upon, yields rose all over Asia. Table 3.1 shows the rapid growth of wheat yields after the mid-1960s compared to the slow increases in cultivated area. This rapid, sustained yield growth translated into major gains in production. Table 3.2 shows the magnitude of these changes for wheat and rice for important regions of Asia and for the world as a whole since that time.

Table 3.1: Annual percentage growth rates of wheat production, yield and area in developing countries, 1948-86.

	Year		
	1948-52/ 1961-65	1961-65/ 1971-75	1971-75/ 1982-86
Production	2.6	5.0	5.2
Yield	1.1	3.4	4.2
Area	1.5	1.6	1.0

Source: CIMMYT 1989, cited by Plucknett 1991.

RETURNS TO RESEARCH

The widespread adoption and large output impact of new agricultural technologies would suggest that agricultural research is a profitable activity. Numerous studies have attempted to estimate the economic returns to research, and they suggest that returns to agricultural research are in fact high. Of course, it is important to keep in mind the caveats suggested in Chapter 1 about estimating the returns to agricultural research: it is necessarily a crude exercise that can never yield precise numbers due to the difficulties of identifying and quantifying gains and apportioning credit to each of several sources. With this in mind, Alston et al. (1998) surveyed 294 studies of the rates of return to agricultural research, representing nearly the entire literature and containing over 1800 separate estimates of the rate of return for both developed and developing countries. Omitting the highest and lowest 2.5 percent of the rates in order to eliminate some implausible extreme values, an analysis of the entire literature showed that estimated annual rates of return averaged 73 percent. In other words, every dollar invested in agricultural research yielded a return of 73 cents in addition to the original dollar. Such a high return would suggest that agricultural research is an unusually profitable economic development investment opportunity.

Table 3.2: Growth in output and yield of wheat and rice in Asia and worldwide, 1961-65 to 1986-90

Crop	Crop/Region	1961-65 mean	1986-90 mean	percent change
Wheat	Output (mmt)[a]			
	World	251	531	
	South Asia	15.5	63.5	300
	China	19.1	90.1	370
	Yield (kgs/ha)[b]			
	South Asia	825	2000	240
	China	775	3025	390
Rice	Output (mmt)			
	World	240	492	
	South Asia	72.7	135.9	90
	China	72.2	176.9	140
	Southeast Asia	49.1	106.9	120
	Yield (kgs/ha)			
	South Asia	1530	2425	160
	China	2550	5450	220
	Southeast Asia	1650	2950	180

[a,b] Output is measured in million metric tons (mmt) and yield in kilograms per hectare (kgs/ha)
Source: Herdt 1997; citing USDA data

Several other publications have surveyed the rates of return to agricultural research in developing countries and found comparable figures. These include Byerlee and Jewell (1997) for maize in Africa, Walker and Crissman (1996) for potatoes worldwide, and Rosegrant and Hazell (1999) for several crops in Asia.

All of the studies found wide variability around high averages; Alston et al. (1998) investigated the sources of variation. For example, they controlled for factors such as the method of analysis, the location and time period covered by the characteristics of the researcher, whether the study was published, whether it covered a single project or an entire research program, what method it used, and several other factors. The major findings were that 1) there was no evidence that the rate of return to research has declined over time; 2) location does not appear to make much difference; 3) returns for long-term processes such as natural resource management have lower returns, which makes intuitive sense; 4) some methodological assumptions and simplifications have led to some overestimates of returns. For example, covering an entire research program instead of a single project reduces returns by an average of 18 percent, which makes sense because this approach reduces the possibility of including success stories but omitting failures. Nevertheless, even if one omits studies that overestimate returns, the rates of return are extremely high by normal investment criteria.

As mentioned above, the returns to many kinds of agricultural research are difficult to capture privately, so incentives for private sector research are lower than would be suggested by these numbers. Nevertheless, the private sector does play a major role in agriculture; in OECD countries about half of all agricultural research is funded by the private sector.

Rosegrant and Hazell (1999) report that the private sector research in India is large and growing. By the early 1990s, private sector agricultural R&D was approximately one-half the level of public sector agricultural R&D; it accounted for more than 10 percent of total factor productivity (TFP) growth in Indian agriculture during 1956-87. The contribution of private research was highest during 1965-75, when it accounted for 22 percent of total factor productivity growth. However, the contribution of private sector industrial research declined as India's trade and industrial policy turned inward and foreign technology was downplayed.

MEASURING THE IMPACT OF POLICY RESEARCH

Better economic policies can save a country billions of dollars, but the benefits can be difficult to measure, and it is difficult to trace them to policy research since there is no linear relationship between the research and policy making. The major contribution of policy research is to provide policy makers with information they can use to make better policies, which in turn can provide welfare benefits to members of the public. In principle this is no different from the impact of research to produce new technology. But more than in the case of technology, the steps leading from research-derived knowledge to benefits are not easily measurable (Smith and Pardey 1997). Policy makers draw from a pool of information for defining and prioritizing problems and finding appropriate solutions; policy research merely adds to this pool of information. This makes it difficult to tie any one piece of research to a certain policy (Norton and Alwang 1997). Policy research can be evaluated for the quality of its output and the process by which the information is communicated. Potential benefits from policy changes can be indicators of quality of output (Islam and Garrett 1997).

Two examples of the impact of IFPRI's policy research are as follows:

- IFPRI research contributed to Pakistan's decision to close wheat flour rationing shops (Islam and Garrett 1997). This World War II era program had outlived its usefulness and was widely seen as a corrupt system that failed to reach the poor. IFPRI was one of many players in the decision to close the shops, but its analytical efforts helped develop a smooth approach to close the program whereby wheat prices remained low when the ration shops closed. Numerous factors enabled the research to lead to successful policy reform: the research was of good quality; it was consistent with previous research; it provided needed quantitative data; it challenged existing institutional arrangements; it offered clear alternatives; it was timely; and researchers built relationships with all influential actors and targeted information about the findings to them.

- In Viet Nam, IFPRI research helped convince the government to relax rice export quotas and internal restrictions on rice trade during the period 1995-97 (Ryan 1999). IFPRI's research found that the trade restrictions transferred income from rice producers to consumers, and from rural areas to urban, but were not especially effective in assisting the food insecure. The present value of the policy changes was approximately $61 million dollars through 1997, and the estimated benefit-cost ratio of IFPRI's policy research is 56:1. Ryan concludes that the main impact of IFPRI's research is that Vietnamese policy makers made the decision to relax trade restrictions earlier than they would have otherwise.

PART II. TRACING THE LINKS BETWEEN AGRICULTURAL RESEARCH AND POVERTY ALLEVIATION

Part II (Chapters 4-8) develops a framework to trace the links between agricultural research and the welfare of poor people and illustrates it with evidence from the literature. The framework, which is introduced in Chapter 4, demonstrates both optimistic and pessimistic views of the relationship between agricultural research and poverty alleviation. It focuses on four interrelated mechanisms through which new agricultural technology can affect poverty, and these four topics are the subjects of Chapters 5-8. They are:

Technology adoption and farmers' incomes

Agricultural wages and employment incomes;

Food prices and accessibility;

Linkages among agricultural technology, economic growth and poverty alleviation.

In some respects it is artificial to separate the discussion into these four chapters, but it is necessary to do so for ease of presentation. Many poor rural households are simultaneously producers, wage earners and consumers, so technical change will have complex, sometimes competing effects on their incomes. Some of the literature reviewed here incorporates this complexity in its analysis, but to keep the presentation simple the different effects on producer incomes, wages and food prices usually are discussed separately in Chapters 5-7. The analytical issues involved in examining these effects jointly are discussed in Chapter 12 on methodology.

4. CONCEPTUAL FRAMEWORK LINKING AGRICULTURAL RESEARCH TO POVERTY ALLEVIATION

The effects of agricultural research on poverty alleviation are complex. They operate indirectly through several channels and depend on a variety of conditioning factors. In addition, they can be examined in a variety of ways depending on whether one considers poverty solely in terms of income and nutrition status or from the broader perspective discussed in Chapter 2. This chapter presents simplified conceptual frameworks of the relationship between agricultural research and poverty alleviation, and then Chapters 5-8 draw on evidence from the literature for a more detailed examination of how the relationship and the conditioning factors work in practice.

The discussion here begins with the case of improved varieties, and a focus on poverty defined in terms of low income and risk of inadequate nutrition. Agricultural research to develop new varieties has an economic impact when farmers adopt the technology.[3] Technological change in turn increases food production and/or reduces production costs. This can affect poor people's incomes in four basic ways: 1) raising the incomes of farmers who adopt the technology (but not those who do not adopt it, 2) changing the demand for agricultural labor, 3) reducing food prices (or dampening food price increases), thus making incomes go further, and 4) possibly stimulating economic growth that may generate additional employment opportunities and increase wages. The magnitude and direction of these effects may vary a great deal depending on a variety of conditioning factors, and there are many indirect effects to consider as well. These four relationships and some of the conditioning factors are discussed conceptually in this section. Subsequent sections then present evidence from the literature, including a discussion of the conditioning factors and indirect effects.

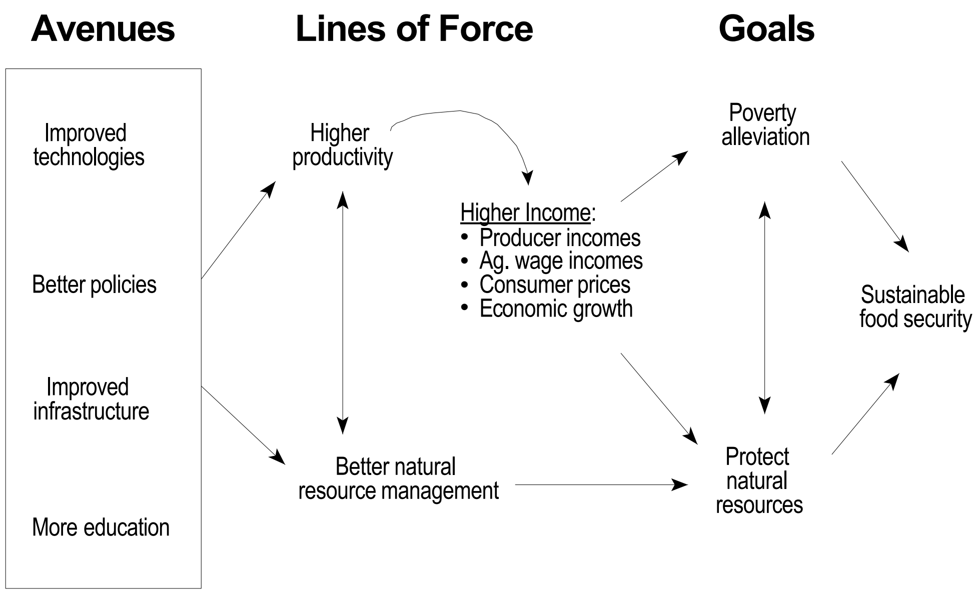
[3] Much of the CGIAR's genetic research produces germplasm for distribution to NARSs that use it to generate finished products adapted to specific needs and conditions. In this case the path between research and technology adoption is more complex than described in this simple discussion.

COMPETING PERSPECTIVES ON AGRICULTURAL RESEARCH'S IMPACT ON POOR PEOPLE

Figures 4.1 and 4.2 offer two frameworks that characterize opposing views of the broad links between agricultural research and raising poor people's income and nutritional intake. Underlying each link in these frameworks is a set of additional complex relationships and these are discussed below. For the moment, only the broad relationships are introduced. First, Figure 4.1 draws on Winkleman's (1998) framework to show an optimistic view of technological change leading to poverty alleviation through positive effects on consumers' food prices, producers' incomes, and laborers' wage incomes. In this scenario higher productivity, better natural resource management and poverty alleviation are mutually reinforcing and lead to achievement of a sustainable food system. Note that in this framework, agricultural research focuses primarily on developing new technologies, but it also provides information to make new technologies more adoptable or better targeted to specific objectives, and to improve policy-making. Other factors besides agricultural research also affect economic growth and poverty alleviation; some of these include infrastructure, education, and exogenous changes in technology and policies.

According to the second framework (Figure 4.2), the overall process of research-led technological change in agriculture is biased towards wealthy people so that the poor are made worse off, and it is dependent on the use of poisonous chemicals that cause disease and death while undermining the natural resource base. The rich get richer while the poor get poorer, and the result is social unrest and a decidedly unsustainable food system. The key relationship according to this framework is that technologies, policies and institutions are biased in favor of wealthy farmers who have unequal access to assets to begin with. Their incomes rise when they adopt the improved technologies while poorer, nonadopting farmers' incomes fall, many agricultural workers are displaced, and some of those who remain suffer from overexposure to poisonous chemicals. Consumers do not benefit from lower food prices because lower farm gate prices translate into

Figure 4.1: The contribution of agricultural research to poverty alleviation



Adapted from Winkleman (1998)

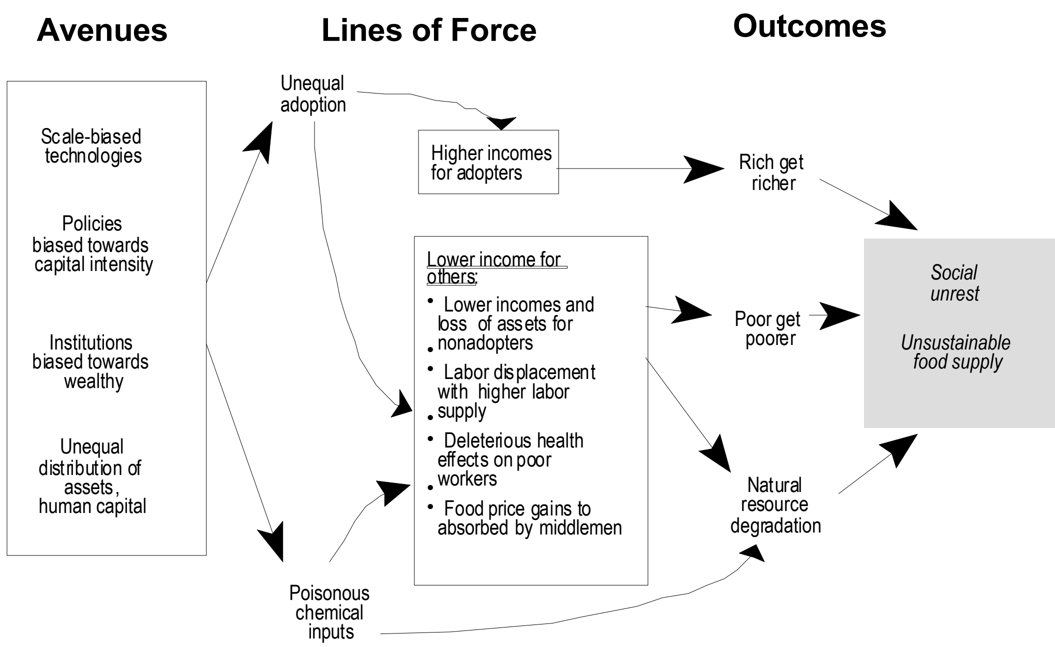
higher profits for middlemen. According to some, the ultimate outcome of this process may be civil strife and warfare (Shiva 1991, Barry 1987).

COMPETING EFFECTS OF TECHNICAL CHANGE ON AGRICULTURAL HOUSEHOLDS

The framework represented by Figure 4.1 does not address the fact that many households have complex livelihood strategies that cross the simple boundaries of farmers, laborers or consumers. They may engage in all three of these activities, farming a small plot and selling some of the product, earning wages as laborers on someone else's farm, and purchasing agricultural products on the market. For such households, the effects of changes in output, prices and wages may have complex effects.

Consider a hypothetical scenario in which an increase in agricultural productivity has four impacts consistent with the optimistic scenario of Figure 4.1: 1) producers have higher output, 2) laborers receive higher wages and more employment, 3) prices fall so consumers pay less for food, and 4) economic growth raises overall sales and employment opportunities. Each of these mechanisms and the conditions under which they may be actually realized are explained in Part II. Under this scenario, the four

Figure 4.2: Negative impacts of agricultural research on poverty



impacts will have competing effects on households that are simultaneously producers, wage earners and consumers. For example, lower food prices mean less income earned through sales but less expenditure through purchases. If a farm household sells part of its production but also purchases food, then whether it benefits from lower prices will depend on whether it is a net seller or net purchaser of food. If the household hires labor in for some operations but hires labor out at other times, then the effect of rising wages on its welfare will depend on whether it is a net buyer or net seller of labor services.

Table 4.1 demonstrates the different effects for a selection of household categories with different asset positions. In this hypothetical scenario, technical change causes the marginal products of land and labor to rise; labor demand rises per hectare but falls per unit produced. Note that for most of the household categories shown the net effect of changing outputs and prices is ambiguous. This means that the theoretical net effect of the changes is uncertain because the various positive and negative effects counteract each other. For example, for the net seller of food/net buyer of labor (row 1), increased agricultural productivity (column 1) may be so great that it outweighs the higher use of labor, the high wage and the lower output price. But the opposite outcome could equally apply and the actual outcome will vary by case. Similarly, in this hypothetical scenario the landless worker who sells labor and buys labor benefits unambiguously from technical change. However, it would be just as easy to construct a case in which the net effect was ambiguous or negative, such as if wages rose but the number of days of employment decreased. In any case, this example shows the complexity of the impact of increased productivity on different categories of households.

Table 4.1: Effects of higher productivity on households with different land and labor asset positions[a]

Household's initial asset position	Direct and indirect effects of agricultural technology improvement					
	food production rises, costs fall	labor demand rises	wage rises	food price falls	net effect	comments
Net seller of food, net seller of labor	+	+	+	-	ambiguous	shift more land to cash crops and sell more; employment income rises
Net buyer of food, net seller of labor	+	+	+	+	+	food expenditure falls, employment income rises
Net seller of food, net buyer of labor	+	-	-	-	ambiguous	shift more land to cash crops and sell more; wage expenditure rises
Net buyer of food, net buyer of labor	+	-	-	+	ambiguous	food expenditure falls but wage expenditure rises
Landless: buyer of food, seller of labor	n.a.	+	+	+	+	food expenditure falls, employment income rises

[a]This assumes that with the technical change the marginal product of land and labor rises, and labor demand rises per hectare but falls per unit produced.

“ ” indicates net benefit for the household category in question

“ ” indicates net loss

“ambiguous” indicates that the outcome depends on which of the various positive and negative effects outweigh each other. For example, for the net seller of food/net buyer of labor, increased productivity (column 1) may be so great that it outweighs the greater use of labor, the high wage and the lower output price.

Source: adapted from comments by Alain de Janvry at IFPRI workshop, May 12-14, 1999

5. TECHNOLOGY ADOPTION AND FARMERS INCOMES

Agricultural research to produce new technology can have a profound effect on agricultural producers' incomes. The relationship between technological change and poverty alleviation through effects on agricultural producers is very complex. Farmers are a diverse population, and typically adoption of a new technology is gradual and partial. It may also be concentrated regionally. As a result, technical change can have variable effects on farmers' incomes both within and across regions.

This chapter examines the distribution of benefits of farmers' adoption of modern varieties and their supporting inputs. Distributional implications for farms of different sizes depend heavily on policies and institutions that condition the incentives and constraints, in turn governing the decision of whether or not to adopt.

EFFECTS OF MODERN VARIETIES ON FARM INCOMES

With new, more productive cultivars farmers can produce more output at the same cost, or the same level of output at a lower cost. This is represented in Figure 5.1a by a shift in the supply curve from S_0 to S_1. Along S_0, farmers who wish to produce more only can do so at a higher cost, say by adding additional inputs. But with the introduction of new technology the supply curve shifts to S_1; at a given marginal cost C_0, farmers can raise the quantity they produce from Q_0 to Q_1. If all farmers raise their production, the higher aggregate output may reduce the price, from P_0 to P_1 as in Figure 5.1b. However, this depends on the nature of the economy. If the economy is closed to trade and the country is about self-sufficient in food, then higher supply will reduce output prices as in Figure 5.1b. Farm profits will not suffer as long as marginal production costs fall by more than output prices. In Figure 5.1b, initial producer surplus is represented by the triangle *abc*, and producer surplus after technical change and a lower price by the rectangle *def*. In this hypothetical case producer surplus is higher after technical change, but this is not necessarily the case.

Box 5.1. Partial equilibrium analysis of producer and consumer surplus

Partial equilibrium analysis offers a simple approach to sorting out the effects of changing supply and demand conditions on the benefits and costs to producers and consumers. The term "partial" indicates that the analysis only examines one sector of the economy in isolation from others; as a result it cannot capture second round effects whereby economic conditions in one sector affect those in others. In the context of this paper, this means that the analysis covers the effects of technology change in agriculture on food prices and wages, without consideration of the implications for other economic sectors and possible feedback effects. This shortcoming is acceptable, for two reasons. First, in general but not always, the direct, first round effects of changes in supply and demand conditions give a good first order approximation of the total effects (Sadoulet and de Janvry 1995). Second, the graphic analysis here is used only to show the principles of relationships between supply and demand when technology changes, without actual data and ignoring the effects of conditioning factors.

The graphic analysis in this Chapter uses the concept of producer surplus to help demonstrate the welfare implications of technical change to farmers. Producer surplus gives a measure of total benefits to producers from supplying products to the market. Producer surplus is the excess of the price for which they sell each unit of their product over what it costs to produce it. This can be seen in Figure 5.1b, where the initial cost of production is given by S_o. This upwardly sloping line indicates that the higher the quantity produced, the higher the unit production cost. At smaller quantities, some low-cost producers are able to supply the product in question at a very low cost, far below the market price of P_o. Because of the high market price, other producers also supply the market at a higher cost of production, and their net revenue is lower. The highest-cost producer is the one whose marginal cost of producing the last unit is the same as the marginal revenue received for that unit, i.e. the price. For all producers as a group, producers' surplus is the total excess of revenue over costs. In Figure 5.1b this is designated by the triangle *cab*.

Consumer surplus provides an analogous measure of consumer welfare. It is defined as the excess of what consumers would have been willing to pay for each unit of a good over the price they actually pay. This review does not show any graphic analysis of consumer surplus analysis. One important caveat about using consumer and producer surplus to measure the benefits of technical change is that the actual shape of supply and demand curves is not known far away from the range of observed prices and quantities (Sadoulet and de Janvry 1995).

Figure 5.1a: Improved technology enables farmers to produce higher output without raising cost.

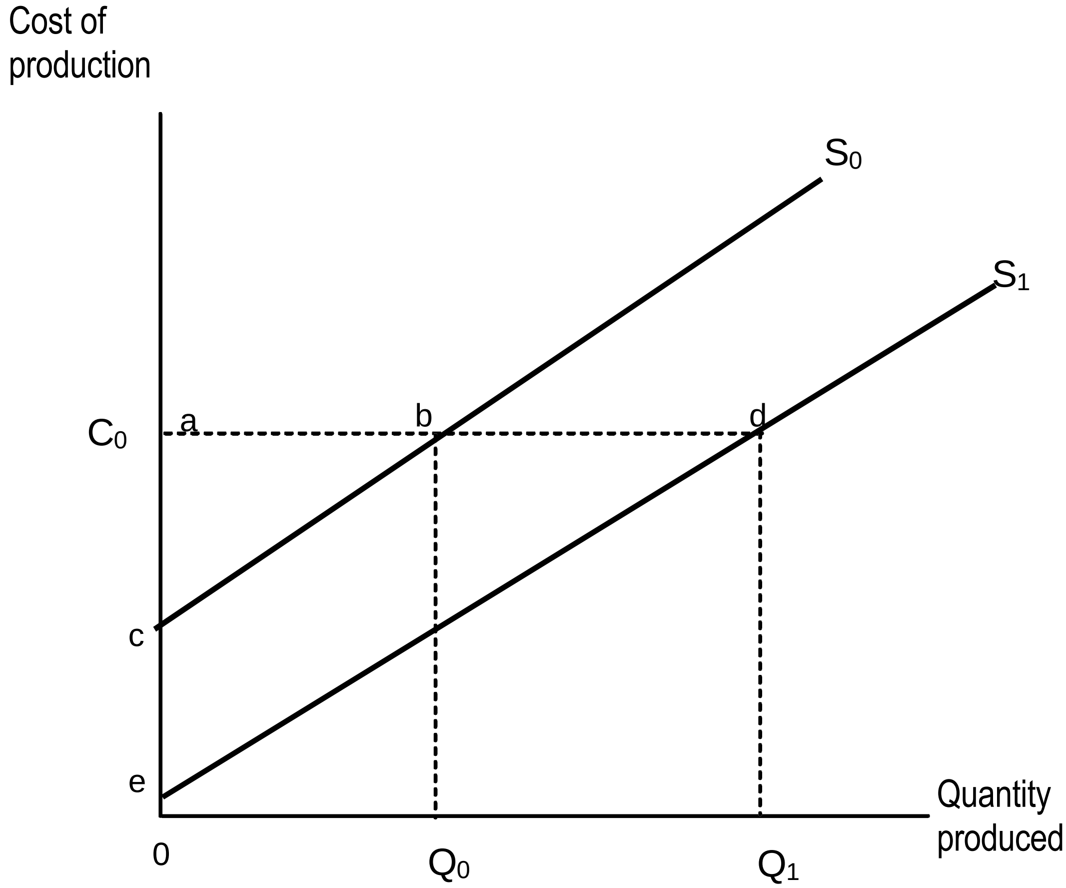


Figure 5.1b: Higher aggregate output without demand shift causes price reduction in a closed economy.

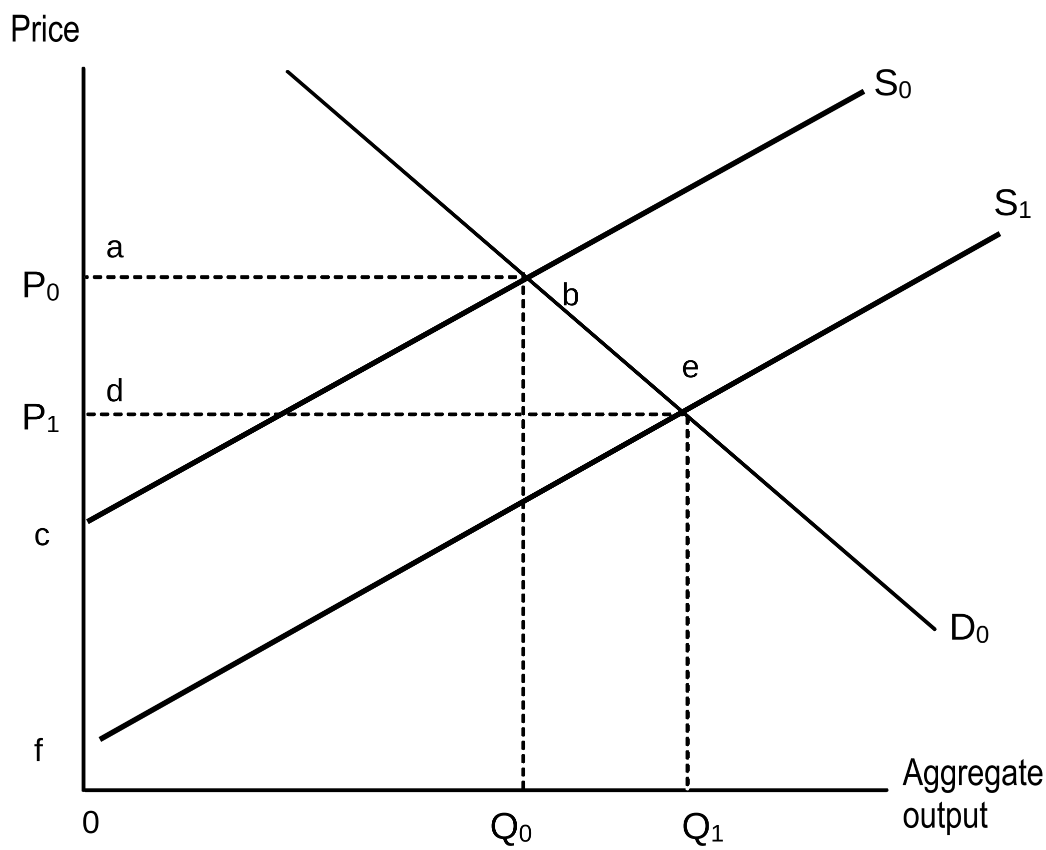


Figure 5.1c: Shift in demand raises price.

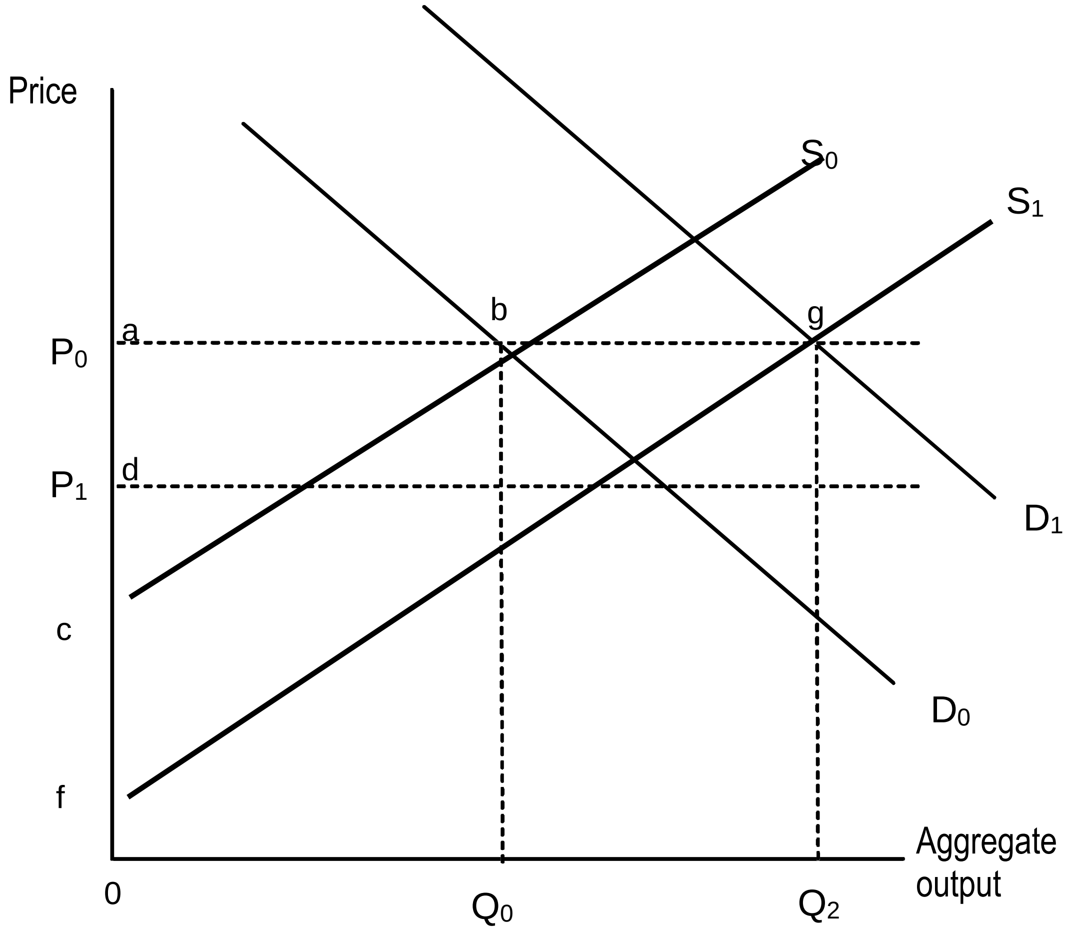
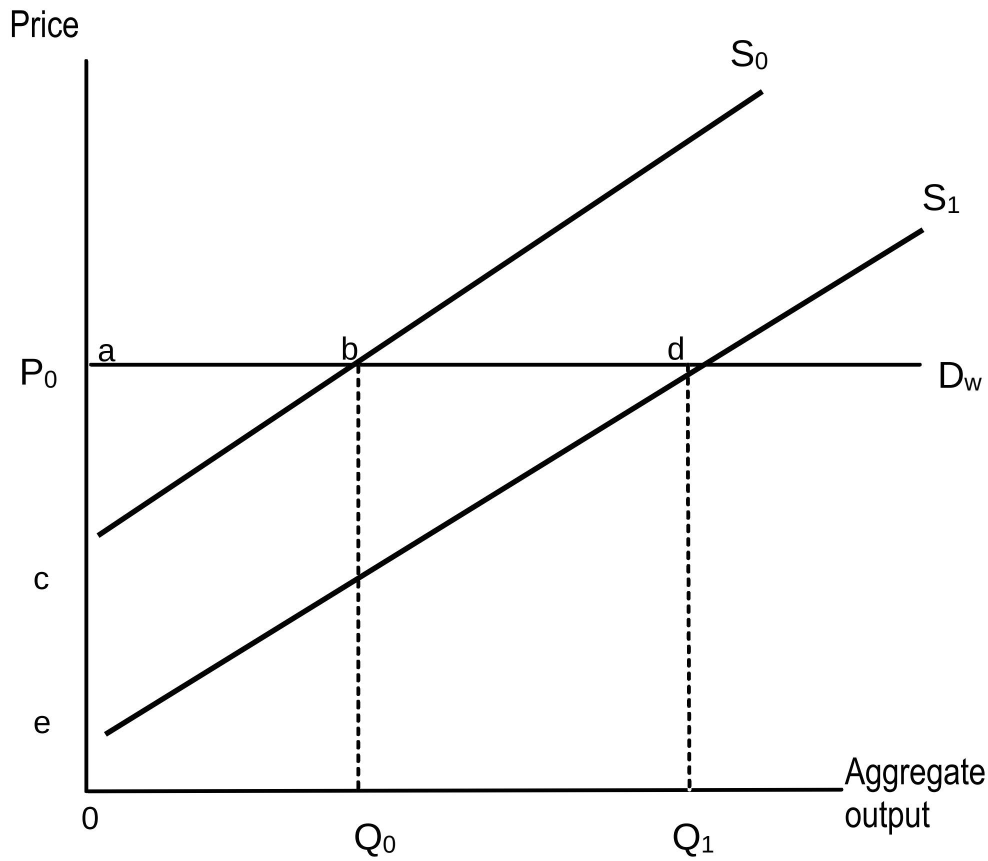


Figure 5.1d: In an open economy, higher output has no effect on price.



In a closed economy in which food demand is rising due to higher incomes or population growth, demand will shift from D_0 to D_1 in Figure 5.1c; in this case output price will not fall by as much or it may even rise if demand shifts faster than supply. In Figure 5.1c, the shift in demand is sufficient to return to the original price at P_0. Producer surplus enjoyed by farmers is represented by the triangle *agf*, unequivocally higher than the initial level of *abc* regardless of the shape of the supply and demand curves.

In an economy open to trade and small enough not to affect international prices, world demand will absorb the additional output with no downward pressure on output price. In this case the demand curve is represented in Figure 5.1d by D_W, at the constant price of P_0. Farmers will benefit unequivocally from lower marginal production costs—they would be able to supply more at a constant price, giving them higher revenue and higher net returns. In Figure 5.1d this is represented by an unequivocal increase in producer surplus from *abc* to *ade.* In a large, open economy whose international trade is large enough to affect world prices, the relationships are similar to those in the closed economy case of Figure 5.1b and 5.1c.

Uneven Adoption

The story remains relatively simple as long as adoption proceeds evenly among rich and poor farmers within a region, but the situation changes if adoption is concentrated among wealthy farmers. If a small number of farmers adopt the new technology, their supply will shift out from S_0 to S_1 in Figure 5.1a, but their increased production will not have much effect on aggregate production. In Figure 5.1b, aggregate output would remain at around Q_0 and price at P_0. The adopting farmers would all earn more, because they could produce more at the same cost and receive the same price. On the other hand, if a large number of farmers adopt the new technology while a smaller number of farmers do not, then the nonadopting farmers may actually become worse off. This is because with higher aggregate output Q_1, price would fall to P_1 in Figure 5.1b (assuming no shift in demand). Adopting farms could remain profitable by producing at a new, lower marginal cost, but nonadopting farmers would face declining net revenues because they would still incur the original, higher marginal cost while receiving a lower price for their output.

Clearly the nonadopting farmers would become worse off in this case; if their returns become negative they would be driven out of business. Even if their returns remain positive, adopting farmers might purchase their land since it would give higher returns to them than to nonadopting farmers. Even though nonadopting farmers would earn revenue by selling the land, they would lose an important asset and means of livelihood.

Reasons for Uneven Adoption

There are several reasons why wealthy farmers might adopt new technology before poor farmers. Wealthier farmers may have better access to *information* about a new technology, perhaps because they are better connected to people in the research and extension system or to representatives of commercial input suppliers. They are also likely to be better able to absorb the *risk* associated with trying out a new technology, whereas a poorer farmer might wait to see how it performs on a neighbor's field. This effect will be greater the more *cash* is required to adopt the new technology. Cash not only increases a new technology's riskiness, but it may also prevent poor farmers from adopting if they lack available cash to make the investment (which will not yield a return until after harvest, several months later). This problem can be solved with easy access to *credit*, but credit is notoriously difficult or expensive for poor farmers to obtain in many developing countries. Inexpensive production credit may be available from banks and cooperatives, but worldwide experience has shown that they are more accessible to wealthy farmers than poor ones. Even where minimum land holding requirements do not bar small farmers from access to institutional credit, high transaction costs in traveling to the bank and negotiating bureaucratic hassles may raise the effective cost until it is prohibitively high. Small farmers are likely to have access to informal credit through village moneylenders, but at a much higher monetary cost (Zeller and Sharma 1998).

As discussed in Chapter 3, the early green revolution cultivars performed best with *irrigation,* and this can be another source of unequal adoption by rich and poor farmers. Credit markets can be particularly important in this context. Under relatively large, publicly-funded irrigation systems, irrigation water may not be distributed any differently than agricultural land per se, so it will not necessarily have any particular implications for distribution of gains between rich and poor farmers within a region. On the other hand, where costly, privately funded wells and pumps predominate, wealthy farmers can more easily invest in irrigation and thus may benefit more from new cultivars. In some areas inequality resulting from the indivisible nature of irrigation wells is overcome by water markets, so that poor farmers with insufficient capital can still buy water from their neighbors (Shah 1993).

Literature on Differential Adoption

Literature on technology adoption is in general agreement that wealthier farmers typically adopt first while their poorer neighbors lag behind. The more important question, as posed above in a theoretical framework, is whether this causes any long term problem for them. Binswanger and von Braun (1993) argued that most literature is in agreement that small farmers adopt modern varieties with only a small lag behind larger farmers, so in most cases farm size differences in adoption disappear. Lipton (1989) found a great deal of evidence to support this pattern. They suggested that while the first adopters of successful varieties gained the greatest rents because they received high prices for their higher outputs, secondary adopters also gained, though not as much. The main loss to them was foregone income that they could have earned by adopting earlier. At the

BOX 5.2. RELATIONSHIP BETWEEN FARM SIZE AND YIELD AS TECHNOLOGY BECOMES MORE CAPITAL-INTENSIVE

Research around the world has shown that small farms generally have higher yields per hectare than large farms (Cornia 1985). This inverse relationship between yield and farm size is attributed to lower labor costs on small farms, mainly through the use of family labor with a low opportunity cost and no supervision costs. Research also shows, however, that this relationship weakens or even reverses as agriculture becomes more capital intensive. Deolalikar (1981), Hanumantha Rao (1975) and Subbarao (1982) all observed this pattern in India and attributed it to higher application of fertilizer and other cash-intensive inputs on large farms. Subbarao took the analysis a step further and showed that a positive relationship between farm size and yield is related to poor institutional conditions that constrain small farmers' access to credit, chemical inputs and irrigation. He found that in institutionally well-developed regions such as Punjab and Haryana, the inverse relationship held even as agriculture became more capital intensive. This suggests that capital intensity per se is not a problem for small farms, but institutional bias is. The disadvantages to small farmers can be overcome by policy reform.

Source: Adapted from Sadoulet and de Janvry (1995:258) same time, Lipton acknowledged that in some cases the costs to later adopters were more severe and this will be discussed more below. Early studies showed overwhelmingly that the adoption of green revolution technologies was concentrated among wealthy farmers, whereas later studies showed that the adoption gap had narrowed (David and Otsuka 1994; Byerlee and Moya 1993; Hazell and Ramasamy 1991, Alauddin and Tisdell 1991, etc.). One reason for more even adoption in later years was an improvement in credit markets, partly due to introduction of government production credit programs and partly due to private initiatives to interlink markets for credit, inputs and outputs, thus making it easier for poor farmers to adopt (David and Otsuka 1994).

Leaf (1983), in a detailed before-and-after field study of a Punjab village, found that there was virtually no institutional credit in 1965, just before the green revolution, and very poorly functioning markets for inputs and outputs. When he returned for additional field work in 1978, new cooperative systems made credit easily available for large and small farmers alike, and other markets worked well too. Small farmers had no difficulty innovating. Finally, even though early adopters often earned high returns, in many cases they also suffered severe losses due to unforeseen technical problems (Walker and Ryan 1990). Accordingly, high returns for early adopters were probably a fair reward for taking a risk.

Role of Preferences

Most studies find that over time, larger farmers retain higher adoption levels of modern varieties even though the gap is narrow. Such discrepancies may arise due to differences in preference as opposed to access constraints such as risk aversion or lack of credit. In other words, small farmers may have different objectives in varietal selection that may cause them to seek different plant characteristics. For example, in a study of women pigeonpea farmers in semi-arid India, Pimbert (1991) found that households with very small holdings producing mainly for domestic consumption will be more interested in features such as taste and storability. If they own livestock they will be interested in fodder quantity and quality, and they may also be interested in varieties superior for use as fuel or even construction material. They may produce one variety for home consumption and another for the market, but the smaller their marketable surplus, the less their interest in growing commercial varieties. Kumar (1994) found a similar explanation for differences in adoption of hybrid maize by farm size in Zambia.

Nonseed Inputs

Small farmers are likely to be able to adopt new cultivars as easily as their neighbors with larger holdings, but other inputs may pose problems. Most seeds for field crops are inexpensive, and almost all of the improved cultivars developed in the green revolution and afterward by the IARCs are open-pollinated varieties that farmers can propagate themselves. If they save seed from year to year they can avoid purchasing it; if not they can buy seed locally from their neighbors. Other inputs, on the other hand, may pose greater problems. Even though chemical inputs are scale neutral in principle, some poor farmers may have difficulty gaining access to the cash needed to buy them every year, in some cases at quite a high cost. Also, there is a risk that they will not yield any return, for example in the event of a drought or severe pest attack. As a result, one might expect to find greater disparity in adoption of supporting inputs than of seeds.

Lipton found more evidence of unequal adoption for supporting inputs than for modern varieties, but it was not overwhelming. In many cases the use of irrigation and fertilizer was independent of farm size. David and Otsuka, in their study of several Asian countries, found only infrequent differences in adoption rates of fertilizer or pesticide by farm size, and in some study areas smaller farms applied more fertilizer than large farms. The nature of modern varieties, described above, suggests that fertilizer may be the input that offers the highest returns.

If modern varieties are adopted evenly but nonseed inputs are not, then input responsiveness will be critical to determining income distribution effects of new cultivars. If improved varieties are highly responsive to inputs, those who have access to them will realize higher yields and incomes than those who do not, even if everyone adopts the new cultivars. Information about modern varieties presented in Chapter 3 provides some clues about the likely role of inputs. Early rice varieties were highly susceptible to pest attack, so farmers had to apply pesticides to obtain high yields and monetary returns. Similarly, as shown in Figure 3.1, achieving high wheat yields required the use of fungicides. The early green revolution varieties were also highly responsive to fertilizer and irrigation. As a result, yield rose disproportionately as inputs were added, and without any inputs new varieties underperformed traditional varieties. On the other hand, the newer modern varieties, while input responsive, also perform well at low input levels. Many modern varieties are now highly resistant to pests and diseases, and farmers can grow them without irrigation (Figures 3.2 and 3.3). Modern varieties often outyield traditional varieties even without input applications, so all farmers can benefit from them (Byerlee 1996).[4]

Key Role of Policies and Institutions

The literature cited above suggests that high input intensity does not cause major income distribution problems across farm size as long as markets for inputs, along with credit to pay for them, work well. The more serious problem is where these markets do not work well. If supply is unreliable, surely wealthier and more influential farmers will have better access to them and negative income distribution consequences will be very real.

Lipton (1989) found numerous cases in which early adopters gained all the benefits of modern varieties and many nonadopters or late adopters were made worse off. In these cases, economic policies related to input supply and land tenure that favored large farmers were typically to blame. Lipton suggested that while policy reforms are of paramount importance, programs supporting introduction of modern varieties should pre-evaluate them in any given land tenure context. If policy conditions are not supportive, technology change will bring harmful results to the poor.

[4] Pingali does state, however, that the new super rice varieties currently under development are likely to be disproportionally responsive to inputs.

One concern about uneven adoption is that if early adopters gain greater profits from agriculture than nonadopters, early adopters will purchase land from their neighbors and land holdings will become more concentrated. Binswanger et al. (1995) point out that from a strictly technical or economic point of view this should not happen because small farmers are actually more efficient than large farmers, and most agricultural technology is scale-neutral. However, as agricultural economies have evolved, market distortions have enabled large farmers to concentrate wealth even though they are less efficient. In feudal societies the mechanisms included biases in assigning tenure rights to powerful classes, tribute systems and slavery. In modern economies the mechanisms are more subtle but still effective; they include credit subsidies linked to land holdings, exemption of agricultural income from taxation, restrictions on market access, etc. All of these factors can contribute to scale biases in agriculture, leading to concentration of landholdings among large farmers.

INTRAHOUSEHOLD INCOME DISTRIBUTION

Introduction of new technology can change income distribution not only across

BOX 5.3. TECHNOLOGY ALONE IS INSUFFICIENT FOR RURAL DEVELOPMENT

Freebairn (1995) notes that debates about the green revolution's distributional impacts are interminable and seemingly irreconcilable. He reviewed every paper he could find on the subject in an effort to explain the divergent findings. Of a total of 324 papers, about 80 percent argued that inequity worsened with the green revolution, but significant variations masked this overall figure. For example, studies covering India and the Philippines, conducted by developing country researchers and using quantitative analysis were more likely to show that the results were equitable, whereas western developed-country authors using a case study approach in other areas were likely to find that greater inequity resulted. Freebirn made no effort to distinguish papers by the quality of their evidence. The findings suggest several things, not least of which may be that researchers on all sides of the debate highlight whatever they feel most passionately about. More significantly, however, Freebairn suggests that divergent findings across locations reflect real variations, which stem from differences in policies and institutions that condition farmers' ability to adopt new technology. He concludes that technology alone cannot solve problems of unequal distribution of productive assets and access to markets and services. Put another way, technology cannot substitute for structural reforms biased against poor farmers.

households, but also within households. Where men and women play different roles in producing agricultural outputs, a change in technology may affect these roles, with possible implications for control over income. This is particularly important in some areas of sub-Saharan Africa where men and women within a household control separate plots of land.

In their study of Mali, for example, Lilja and Sanders (1998) explain that most resources and agricultural revenues are controlled by men on “communal” or household (extended family) plots on which all family members contribute labor. Where sufficient land is available, family members are allocated their own “private” plots that they can cultivate after they have met their obligations on communal plots and in other household activities. Introduction of a new, more productive cotton technology led women to reallocate time away from their private plots to the communal plots. They earned more income for their labor on the communal plots, but this gain was outweighed by losses due to reduced production on their private plots. The authors suggest that more attention needs to be paid to the crops that women grow on private plots, and to changing social institutions to increase women’s bargaining power.

A study of rice farming in Gambia by von Braun and Webb (1989) supports the notion that institutional changes may be more effective than targeting research to “women’s crops.” In their study area, rice was traditionally planted by women on their private plots, but with the introduction of more productive technology it became a communal crop controlled by the male head of the extended household. In response to this change, women began cultivating some other cash crops, such as groundnuts and cotton, which were not traditionally thought of as women’s crops. The authors found that women’s labor productivity was lower than men’s due to lack of access to inputs and conflicts with other demands on their time. Women would benefit from better access to credit and other institutional changes. One change mentioned by both Lilja and Sanders (1998) and von Braun and Webb (1989) is movement toward smaller, nuclear family groups. The smaller groups and particularly women gain greater autonomy with this change. Sanders et al. (1996) further point out the need to combine technical improvements with measures to save women’s time and increase their bargaining power.

INTERREGIONAL ADOPTION DIFFERENCES

Inter-regional differences in adoption of new technologies is commonly cited as an important source of inequity resulting from modern varieties. As described in Chapter 3, green revolution varieties performed better under irrigated conditions with favorable access to input and output markets, so areas with unfavorable climates and poorly developed markets will be disadvantaged.

The mechanism by which farmers in nonadopting regions may suffer is similar to that described in Figure 5.1b for the case of adopting and nonadopting farms within a region. If farmers in the favorable region adopt but those in the unfavorable region do not, aggregate expansion of supply will cause prices to fall, reducing incomes for farmers in the unfavorable regions and possibly driving them out of business. Lipton (1989) found that in most cases of regional variation in adoption, nonadopting regions did suffer through the mechanism of reduced output prices described in Figure 5.1b and explained above. Likewise, in more recent studies Hazell and Ramasamy (1991) found greater income disparities between irrigated and unirrigated villages in India, and Goldman and Smith (1995) found the same in dry areas of India and Nigeria. David and Otsuka (1994) found that over time, farmers in nonadopting regions shifted to other crops in which they had a comparative advantage. They also benefited from nonfarm sources of income. These factors reduced the extent of income redistribution resulting from uneven regional adoption.[5]

Some critics may argue that even changes in relative incomes between regions have negative social consequences and thus should be avoided. However, as mentioned

[5] The effects of uneven regional adoption on landless workers received detailed attention in the David and Otsuka study and this is discussed in Chapter 6.

in Chapter 3, there is a certain inevitability of regional variation in agricultural production since it is so dependent on natural agroclimatic conditions. The best way to overcome this problem may be to support the development of the nonfarm economy in unfavorable regions (Fan et al. 1998).

SOCIAL SCIENCE AND POLICY RESEARCH

An obvious example of the value of social science research in making the benefits of new technology more equitable is the work that revealed the distributional problems of the early green revolution and the need for changes in policies, institutions and plant characteristics. Early studies of the green revolution, mentioned above, found that structural biases in the economy constrained small farms from adopting new technologies. These findings led to measures to facilitate markets for credit, inputs and outputs, along with plant breeding for tolerance to a variety of crop stresses that are more difficult for poor farmers to manage. Recent studies of green revolution areas have shown more equitable distributional impact as a result.

Another example of useful social science research concerns soil and water conservation (SWC) in rainfed, marginal areas of Africa, South Asia and Southeast Asia. Social science research in all these places has contributed to the design of better of soil and water conservation programs promoting techniques useful to small farmers in unproductive, degraded areas. Farmers in these unproductive areas are very poor, and soil erosion threatens their most important productive asset. Soil conservation programs in these areas have a long record of failure (Pretty and Shah 1999) that SWC officials attributed to lack of understanding or interest by farmers. Studies by Reij (1991) in the Sahel, Fujisaka (1989) in the Philippines, and Kerr and Sanghi (1992) in the semi-arid tropics of India, all made it clear that in fact the problem was the inappropriate approach of SWC programs. These top-down programs imported techniques from large farms in favorable regions and attempted to impose them without consulting farmers about how they would fit into local farming systems. Together with a number of NGOs working on the same issue, social science researchers identified indigenous soil and water conservation practices and explained how they worked and why they made sense under local conditions. Findings and recommendations of these studies have been successfully tested in numerous small-scale SWC programs operated by NGOs. In India they are now recognized and approved under the largest government-sponsored SWC programs, but it is too soon to know what its impact will be.

6. AGRICULTURAL WAGES AND EMPLOYMENT INCOMES

Raising incomes from wage employment is critical to poverty alleviation because so many of the poor are primarily landless agricultural workers. As with other impacts of agricultural research, those on wage employment are both indirect and partial due to the confounding effects of other factors that drive agricultural wages. These include population growth, labor migration, economic policies and changes in the nonagricultural sector. This chapter first shows that improved varieties require additional labor and then discusses the theoretical effects of higher labor demand on wages and employment. Agricultural labor demand is highly seasonal, so rising wages in peak seasons can coexist with unemployment in slack seasons. Also, rising wages due to labor scarcity can generate incentives for farmers to mechanize certain operations, dampening the effect of rising wages. Laborers' income changes are discussed both in absolute terms and in comparison with those of landowners; it is important to note that laborers' incomes could rise in absolute terms yet income inequality could increase if landowners' incomes rise by even more.

EFFECTS OF MODERN VARIETIES ON EMPLOYMENT AND WAGES

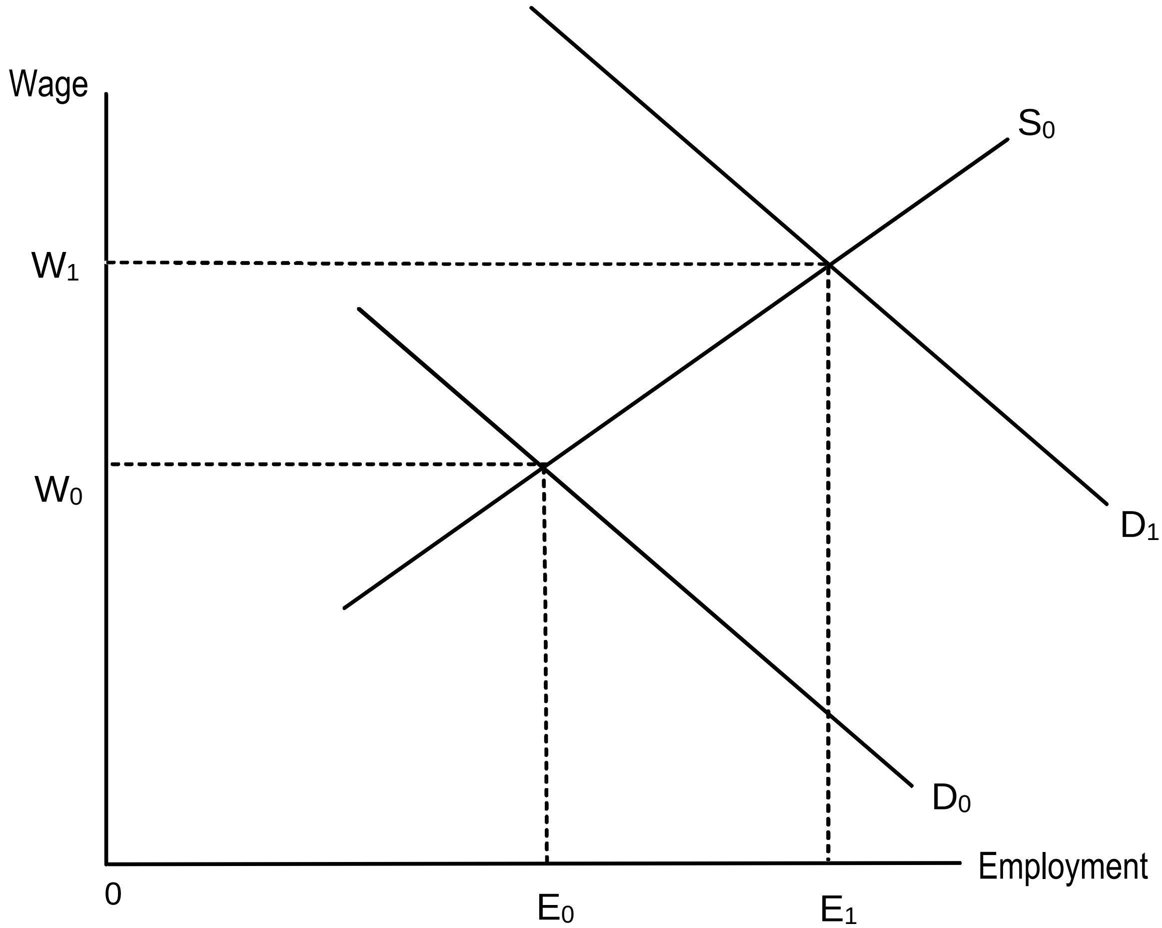
Modern varieties are labor-using because, as discussed in Chapter 3, higher yields imply a larger crop to harvest and process. As a result, farms that adopt modern varieties are likely to use more labor than those that do not. By offering higher returns, they also create an incentive for better crop management, for example through weeding, which also uses additional labor. It is important to distinguish between the effects of irrigation and those of modern varieties in generating demand for labor, but also to recognize their complementary effects. Irrigation raises production and requires additional labor for crop care just as modern varieties do. Irrigation also enables multiple cropping in many dry areas, thus creating a large boost in labor use. Short duration modern varieties can enhance this effect by enabling farmers to grow three crops per year rather than just two.

The implications for wages and employment of the rise in labor demand depend on several factors. If labor is in excess supply, i.e. unemployment is high, then higher labor demand will raise employment but wages will not necessarily rise, whereas if labor is scarce then higher labor demand will raise wages. Agricultural labor demand is highly seasonal, so areas where productivity has increased can be characterized simultaneously by higher wages during peak harvesting and planting seasons and low wages and unemployment during slack periods.

Figure 6.1 shows the relationship between labor demand and supply in simple theoretical terms. In Figure 6.1a, initial labor demand is represented by D_0, which shows that potential employers will want to hire more labor as wages fall, and vice versa, other things being equal. With widespread adoption of modern varieties labor demand shifts out to D_1, meaning that any given wage rate employers are willing to hire more labor than previously. If labor supply is neither completely elastic nor completely inelastic[6], meaning that additional laborers are available but will demand a higher wage before agreeing to work, then increased labor demand will raise employment from E_0 to E_1 and wages from W_0 to W_1. On the other hand, as shown in Figure 6.1b, if unemployment is high labor supply may be highly elastic, meaning that additional workers will join the labor force as soon as jobs open up. Employment will rise but wages will remain constant. If labor is highly inelastic, meaning that few additional workers will be available no matter how high the wage rises, then higher labor demand will raise wages substantially while employment rises only slightly, as in Figure 6.1c.

[6] Elasticity is the percentage change in the value of one variable in response to a percentage change in another. Highly elastic supply means that supply changes in response to price changes. Inelastic supply means that the supply does not respond to changes in price.

Figure 6.1a: Wages and employment rise when labor demand shifts out.



There is virtually no debate that modern varieties require more labor per hectare, but the question is whether this translates into higher wages and employment in practice. Several publications provide evidence that in fact it does:

- Alauddin and Tisdell (1986) found that unemployment had fallen in Bangladesh with the introduction of modern varieties relative to what it would have been with traditional varieties. Also in Bangladesh, Hossain et al. (in David and Otsuka 1994) found that in adopting villages there was a declining incidence of long term attached labor contracts. These contracts were associated with poverty; they paid much less than daily-rated employment and workers usually entered them to pay off a debt.

- Goldman and Smith (1995) found the same result in both India and northern Nigeria. Higher demand for labor arising from more intensive cultivation benefitted the poor. Leaf (1983) and Abler et al. (1994) found the same thing in Punjab.

Figure 6.1b: Employment rises but wages do not if demand shifts out and labor supply is elastic.

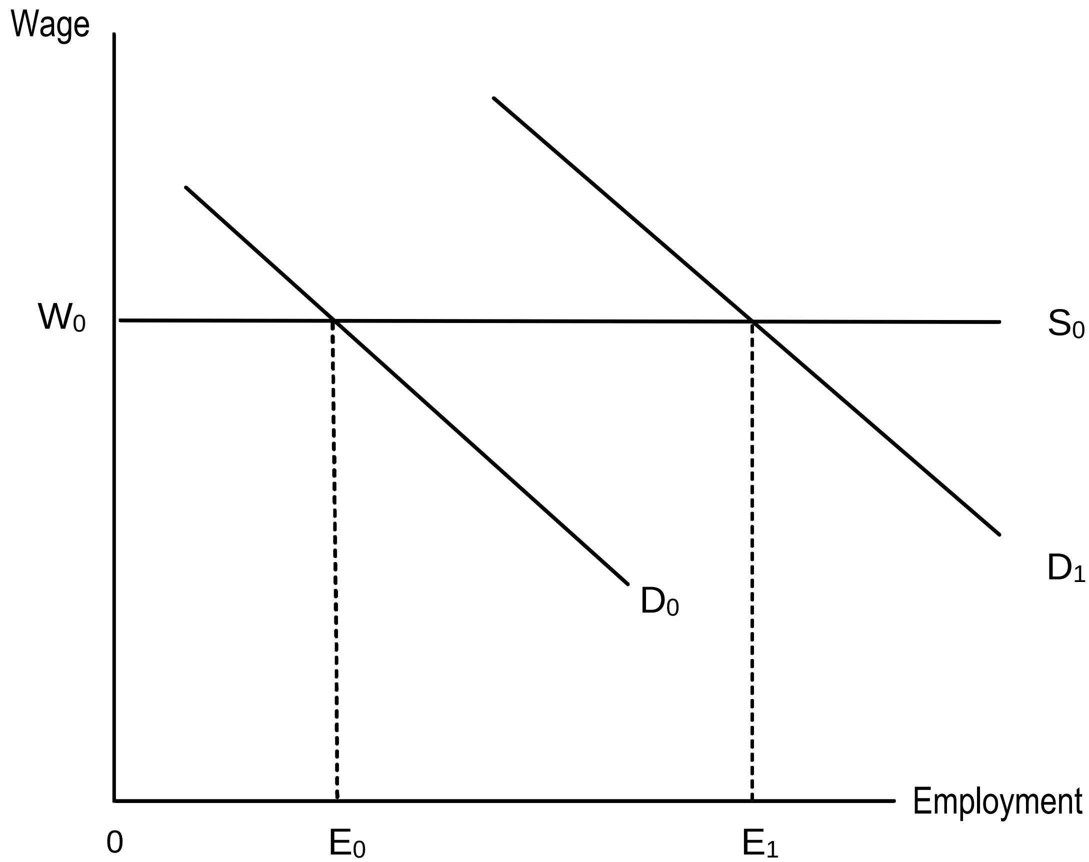
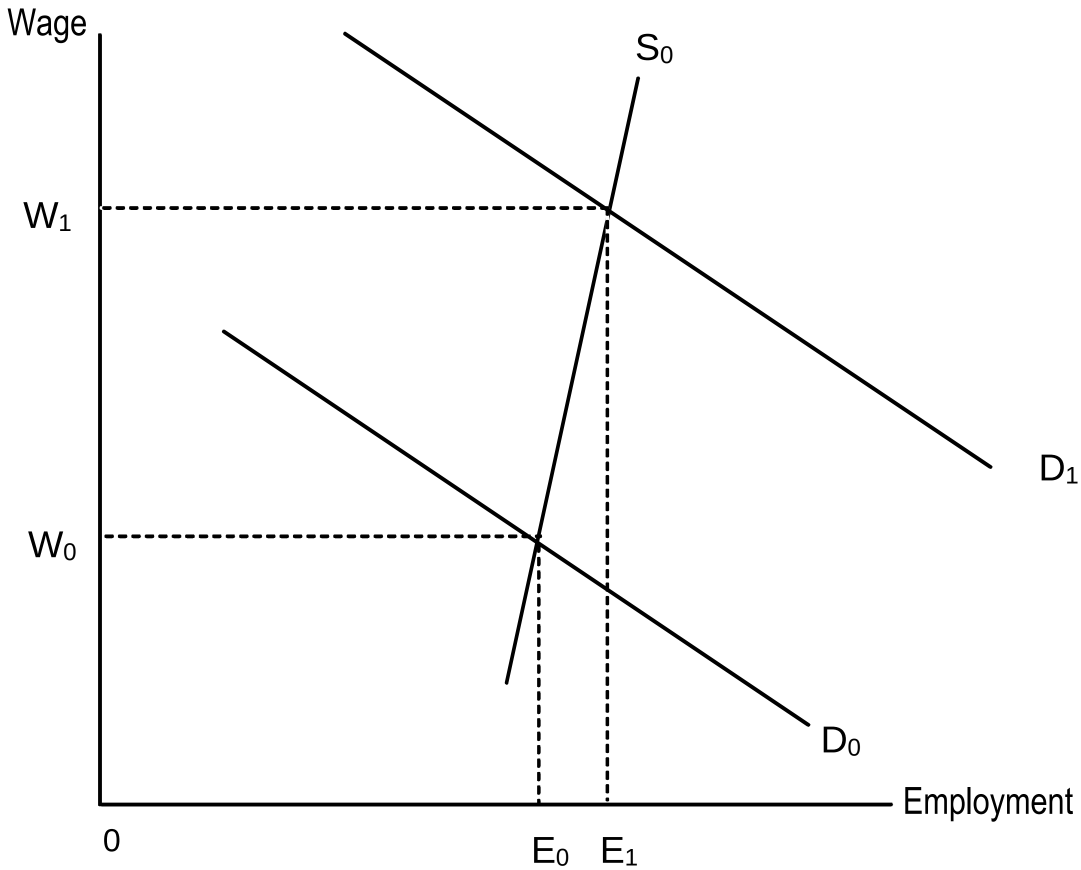


Figure 6.1c: Wages rise sharply if labor supply is inelastic and demand shifts.



- Case studies of several Asian countries in David and Otsuka (1994) showed that labor demand increased with the adoption of modern varieties, even following the introduction of mechanical threshers. This substantiated findings from another cross-country study of improved rice technology by Barker and Herdt (1985). In the Thailand case study, irrigation contributed to increased labor demand, but when the analysis controlled for irrigation the pure effect of modern varieties on labor demand remained positive (Isvilanonda and Wattanutchariya). In Nepal (Upadhyaya et al.) the labor demand effect of modern varieties was positive but small; the authors believed that this was because Nepalese farmers used little fertilizer. In the India study

(Ramasamy et al.), labor use increased by 62 labor-days per hectare due to modern variety adoption.

- A counter example comes from adoption of hybrid rice in China, which actually saves labor by 4 percent compared to improved open-pollinated varieties due to the fact that it requires less land preparation and no plowing (Lin 1994, in David and Otsuka).

POPULATION GROWTH AND LABOR MIGRATION

Population growth raises labor supply and this means that labor demand must grow at the same rate just to avoid an increase in unemployment. As a result, under rapid population growth any upward pressure on wages resulting from adoption of modern varieties is dampened by the effect of rising labor supply. This is a particularly important problem given that the highest population growth in developing countries is among poor people with lower education and fewer work skills (Lipton and van der Gaag 1993). In developing countries with predominantly rural populations where agriculture is the dominant economic sector, these workers flood the agricultural labor market and it should not be surprising if wages do not grow quickly. Figures 6.2a-d show the growth in the total labor force between 1960 and 1997 for Sub-Saharan Africa, China, Southeast Asia and South Asia, along with the share employed in agriculture. It shows that in absolute terms, agriculture has done an impressive job of employing additional workers as discussed above. On the other hand, the figures also show that the total labor force has grown by even more than the agricultural labor force and this helps demonstrate the magnitude of the employment challenge.

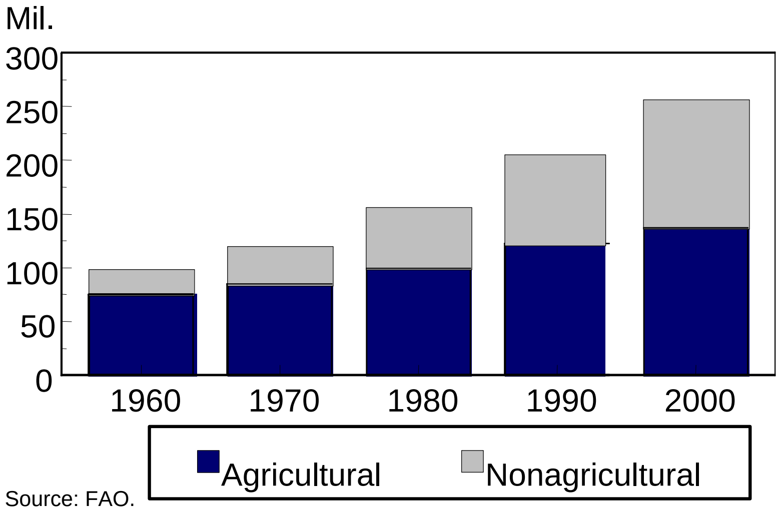
Compounding the labor supply effect of population growth in many high productivity areas is that of labor in-migration from other regions. Since population growth and labor migration both raise the labor supply, evidence on both of them is presented here together. A conceptual analysis of labor migration and a discussion of its effects on low productivity areas are offered separately below. Several studies document the dampening effects of population growth and in-migration on increased demand for labor:

- Pinstrup-Andersen and Hazell (1985:11) found that considerable wage increases from the green revolution were tempered by migration, population growth and mechanization (discussed further below).
- Anderson et al. (1988b) found that the amount of hired labor had increased in several countries with modern varieties, but wages had not. This is consistent with an elastic supply of labor under population growth. Labor supply in Punjab, India, was elastic due to migration from neighboring states with less demand for labor. In Punjab's Ludhiana district, out of nearly 19 man days per acre used for paddy harvesting, nearly 14 came from migrant labor, 2 from family and 3 from permanent hired labor (Laxminarayan, no date).
- Studies in Bangladesh are less likely to show rising wages than in other countries. Khan (1990) and Alauddin and Tisdell (1986), for example, showed stagnant wage growth and population growth certainly was a contributing factor.

CAUSES OF LABOR MIGRATION AND ITS EFFECTS ON REGIONAL INCOME DISTRIBUTION

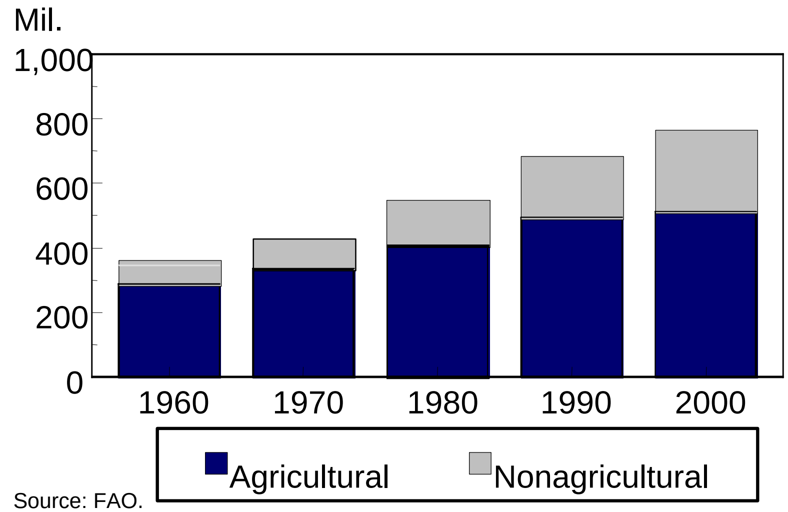
David and Otsuka (1994), in their study covering several Asian countries, also stressed the importance of labor migration from nonadopting to adopting regions. They pointed out that the opportunity to migrate is critical in enabling poor people in nonadopting regions to benefit from technical change elsewhere. In theory, migration will continue from nonadopting to adopting regions until wages are equalized between the two, or at least until the difference in wages reflects only the costs of migrating. If there are barriers to migration, on the other hand, wages will not equalize and workers in the nonadopting region will remain worse off. As David and Otsuka point out, migration is not costless and regional wage differences will reflect the costs of moving from one region to another. Such costs can take several forms, such as negotiating government restrictions on population movement, transport and lodging costs, social costs and significant personal hardships that may not show up as economic costs.

Figure 6.2a: Growth of the labor force in Sub-Saharan Africa.



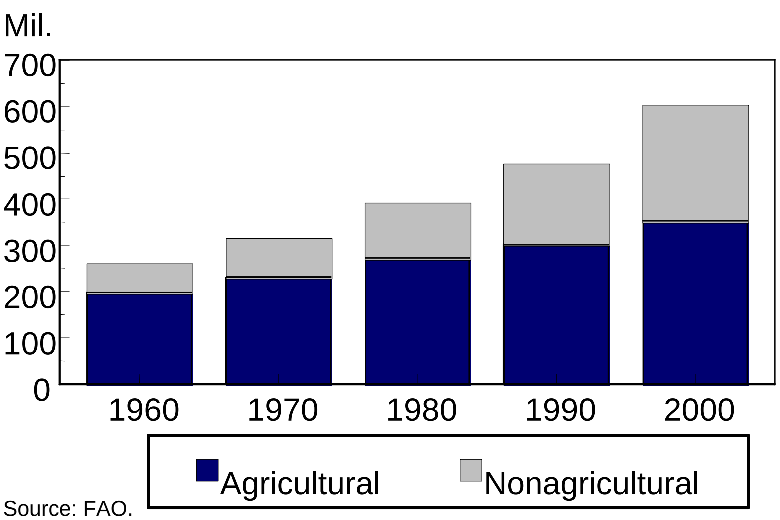
Source: FAO.

Figure 6.2b: Growth of the labor force in Southeast Asia.



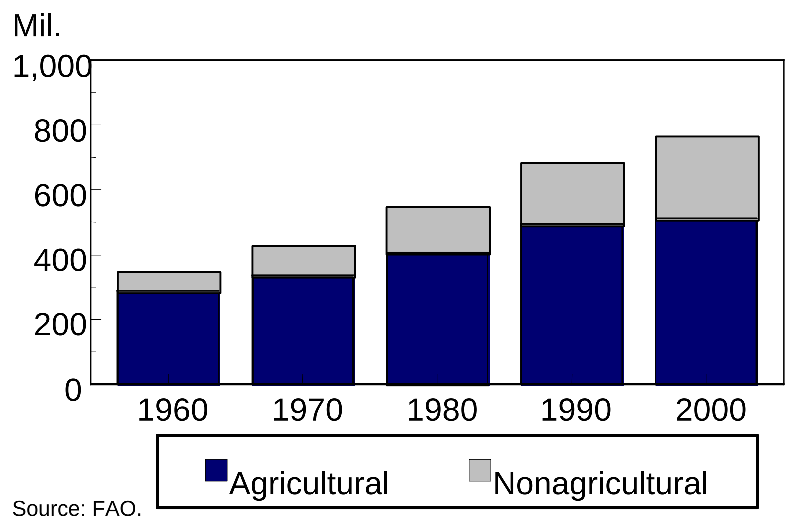
Source: FAO.

Figure 6.2c: Growth of the labor force in China.



Source: FAO.

Figure 6.2d: Growth of the labor force in South Asia.



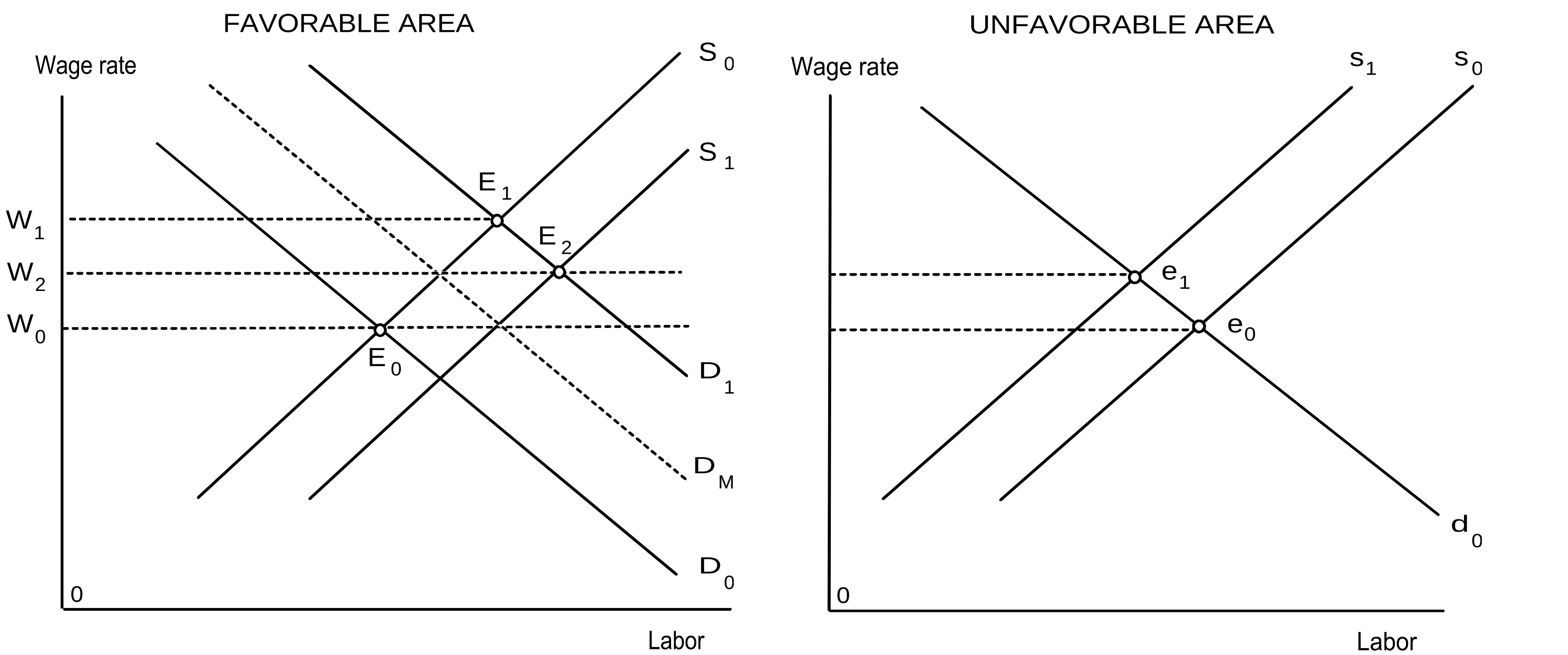
Source: FAO.

Nevertheless, evidence shows that when migration is feasible, many people use it as an opportunity to earn higher wages. Figure 6.3 shows how this works in a theoretical framework with equal initial input and output prices between regions and no costs of migrating. In the favorable environment, the initial wage W_0 is established at the equilibrium point where supply of labor is equal to demand in both regions ($S_0 = D_0$ in the favorable, adopting region, and $s_0 = d_0$ in the unfavorable, nonadopting region). When technological change takes place in the favorable region, demand for labor rises to D_1, causing the wage to rise to W_1 at a new equilibrium of E_1. Meanwhile the wage in the nonadopting area remains at the original, lower level of W_0, and this induces some people from the nonadopting region to migrate to the adopting region. This results in a reduction in labor supply in the nonadopting region and an increase in supply in the adopting region. The labor supply curve in the nonadopting region shifts back from s_0 to s_1, while that in the adopting region shifts out from S_0 to S_1. These simultaneous, opposite shifts take place until the wages in the two regions are equalized at W_2. This new equilibrium wage is higher than the original wage W_0 and lower than W_1, the rate to which wages rose in the adopting region following technical change.

The implication of this model is that labor incomes rise in all regions even from technical change confined only to certain regions. Evidence from the studies contained in David and Otsuka (1994) supports their model. Technology adoption is indeed uneven between favorable and unfavorable environments, and workers do migrate from the unfavorable to the favorable environments until wage differentials reflect the costs of migrating. This pattern was found quite clearly in the Philippines, Indonesia, Bangladesh, Nepal and India. The Thailand study appeared to show the same pattern but poor data made it difficult to confirm.

Renkow (1993), in a study of Pakistan, found that technical change in favorable, irrigated areas, had a much greater poverty alleviation impact than technical change in less favorable rainfed zones. The primary reason for this is that 90 percent of Pakistan’s wheat is produced in irrigated areas, so changes in the irrigated sector have a larger overall impact than those in the rainfed sector. Rising production in irrigated

Figure 6.3: Differential technology adoption and inter-regional wage equalization through labor migration.



agriculture had a much greater positive effect on wages than higher production in the rainfed sector.[7] Accordingly, Renkow concluded that Pakistan's traditional allocation of most of its research resources to the irrigated sector is justified on both efficiency and equity grounds.

Rosegrant and Hazell (1999) suggest regional disparities may be easier to overcome when the nonagricultural economy is a strong source of employment and infrastructure is in good shape. This will reduce the impetus to migrate but also facilitate the process when it takes place. Fan et al. (1998) recommend increased public investment in roads, agricultural technology and education in less favorable agroclimatic areas.

DISTRIBUTION OF INCOME BETWEEN FARMERS AND LABORERS

How gains from increased productivity are distributed between laborers and landowners depends on another complex set of relationships. The critical issue is supply elasticity; gains to technical change accrue in the largest proportion to the factor of production with the most inelastic supply. If land was abundant and labor was scarce, productivity growth induced by technical change would raise wages and expand the area cultivated. As long as land were highly abundant this could happen without a major increase in land values, and the situation for laborers would look like that in Figure 6.1c, where employment income rises sharply. Where land is scarce and labor is abundant, on the other hand, cultivated area cannot be expanded easily and existing land is likely to become increasingly valuable. Figure 6.1c would describe this situation if it referred to supply and demand for land instead of labor. This is the situation in most of the green revolution areas of Asia because nearly all the high quality land is already cultivated.

In the Indian Punjab, the rate of growth in agricultural wages from 1970-71 to 1983-84 was only half the rate of growth of labor productivity in wheat (Bhalla et al. 1990). Laborers appeared to have benefited in absolute terms from higher wages, but

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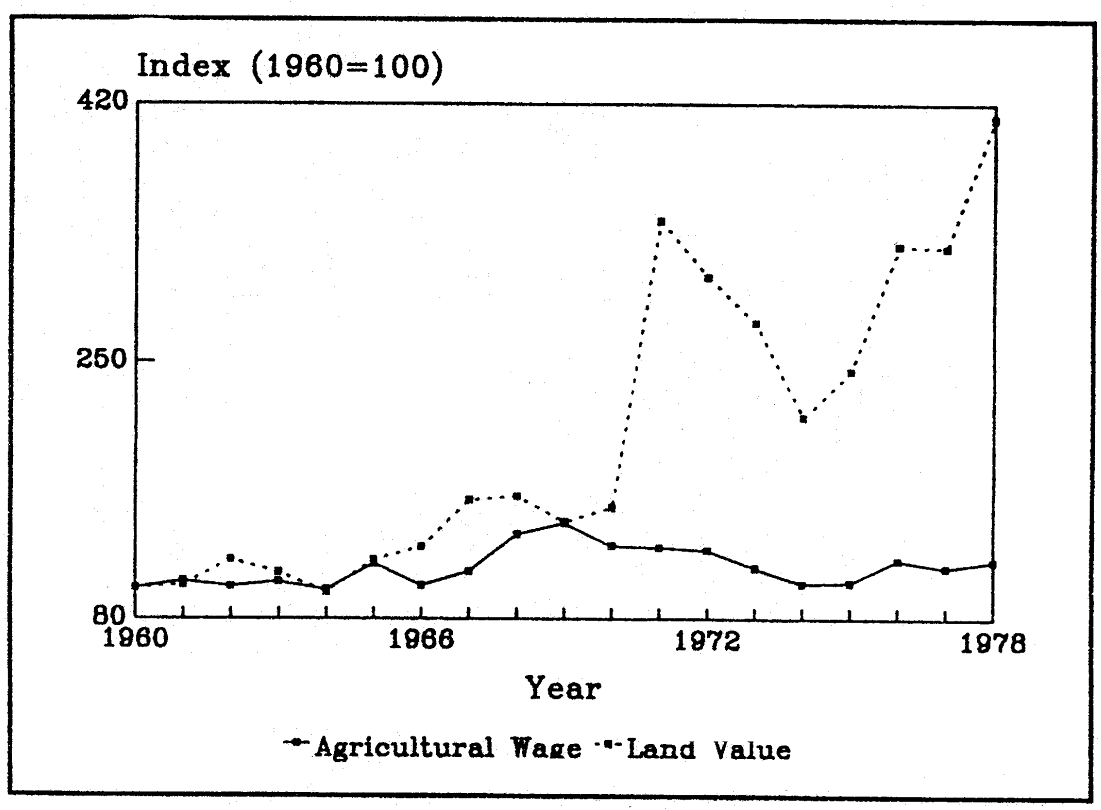
[7] Rising production in the irrigated sector also had a highly positive effect on food production; this is discussed in Chapter 7.

many were still in poverty. Labor supply was elastic due both to population growth and migration from neighboring states.

Numerous studies found that even when wages rose in absolute terms, land rents rose by more for reasons described above (e.g. Warr and Coxhead (1993) and Bautista (1993) on the Philippines, Abler et al. (1994) and Praladachar (1983) on India, Alauddin and Tisdell (1991) on Bangladesh). Figure 6.4 (Abler et al. 1994) shows this effect vividly for the case of India. It suggests that even if poor people's incomes increased gradually with rising wages, the greatest gains were capitalized into land values, thus raising landowners' wealth. However, poor people also gained due to a fall in food prices, which made their incomes go further. This is discussed further in Chapter 7.

Figure 6.4 Punjab wages and land values



On the other hand, Hazell and Ramasamy (1991) found that landless laborers gained proportionately the most among all groups they examined in North Arcot district of Tamil Nadu, India due to steady growth in wages and employment. Several important factors contributed to this finding. In particular, the agricultural labor force grew more slowly than overall population due to rural-to-urban migration and growth in nonfarm employment. At the same time, the growth in wages was slow enough to avoid widespread agricultural mechanization.

Quizon and Binswanger (1986), also in India, found that even though land values climbed much higher than wages, rural income distribution remained stable because laborers had more days of employment and food prices dropped substantially.

Renkow's (1993) study of Pakistan helps explain these competing findings. He found that whether farmers or laborers (more accurately, net producers or net consumers) gained the most from technical change in irrigated wheat production depended on government price policy. In Pakistan the government controlled wheat prices, so higher production had little effect on price. In this case wheat producers gained greatly, because they received a constant price per unit for a larger level of output. Wage earners gained due to higher wages, but their gain was much less than that of producers. In a simulation analysis in which prices were determined by supply and demand, on the other hand, technical change in wheat raised output and caused a sharp decline in wheat prices, because wheat demand was less elastic than output supply. In other words, consumers would not buy additional grain as fast as farmers could increase its production. All wheat farmers, even those adopting the new technology, would lose income under these circumstances. Wage earners, on the other hand, would still benefit from higher wages.

Leaf (1983), in his detailed study of an Indian Punjabi village conducted in 1965 and 1978, found a host of positive changes, with laborers gaining at least as much as others. Labor families were far better off than before despite significant mechanization and in-migration. They had better working conditions, many more days of employment and higher daily wages that included three daily meals. Whereas previously daily work was organized at the last minute and carried a high risk of unemployment, by 1978 it was often negotiated weeks in advance, so that groups of laborers could plan their time and cover several jobs in a day. Many farmers preferred to hire workers on a seasonal basis in order to avoid labor shortages in peak periods. In contrast to the case of attached labor contracts described above, such workers were very well paid and had good security. Leaf found no evidence of landless families forced to migrate due to poor economic conditions. On the other hand, many landed families had done so well that they migrated to cities for education and often remained there to take advantage of economic opportunities even better than those they had left behind.

One notable feature of productivity growth and labor demand in India is that productivity growth generates less employment today than in the past. Studies suggest that the while in the 1970s a 1 percent increase in agricultural output generated an additional 0.4 percent growth in agricultural employment, by 1990 this number had fallen to 0.1 percent (Bhalla et al. 1991). Long-term wage growth appears to be the reason for this finding.

OTHER NEGATIVE EFFECTS OF MODERN VARIETIES ON WORKERS

One important noneconomic impact of the introduction of modern varieties was on that of pesticide use on health in Asia. As mentioned above, green revolution rice varieties were highly susceptible to pest attacks, and researchers and farmers alike responded by spraying high volumes of highly poisonous chemical pesticides. Two studies showed a very high human cost to this work, which fell upon small farmers and laborers in rice growing areas. Rola and Pingali (1993) estimated the health costs in economic terms, while Loevinsohn (1987) conducted an epidemiological study in which he estimated that the accepted figure of 10,000 Asian deaths from pesticide poisoning was a substantial underestimate. As mentioned above, the research system has responded to this problem by developing new, pest resistant varieties and integrated pest management approaches that use less pesticide.

Alauddin and Tisdell (1991) argued that introduction of modern varieties will hasten the disappearance of common property lands due to their impact on raising land prices. They suggested that, as land prices rise, there would be greater incentive to privatize common resources for grain production. This hypothesis is difficult to test because common lands have been privatized rapidly in many places, even without rapid technical change. Also, even without modern varieties land for food production would be at a premium, and privatization would probably still take place.

AGRICULTURAL MECHANIZATION, EMPLOYMENT AND LABORERS' INCOMES

From a purely economic perspective, in the absence of economic policies that would change relative prices, machines are likely to be in demand where labor is scarce relative to land, thus making labor resources go farther to take advantage of abundant land. The history of American agriculture is characterized by a great deal of innovation in mechanization enabling farmers to cultivate large expanses of land with relatively little labor (Olmstead and Rhode 1988). At the same time, even in countries generally characterized by abundant labor, machines are often in demand during peak seasons when labor may be scarce temporarily. Economic policies can play a strong role in determining the conditions under which farmers demand agricultural machines; this topic is discussed below.

Evidence on machinery adoption suggests that it results from a variety of factors, not just introduction of high yielding varieties. Important factors include irrigation, rising wages, higher costs of animal power and subsidies to machinery adoption. Irrigation enables multiple cropping so that machines can be used all year long, thus raising capacity utilization and greatly raising revenues relative to costs. High-yielding varieties, meanwhile, are often of short duration, facilitating multiple cropping which is highly conducive to mechanization. Higher output and multiple cropping means that labor and draft animal power are at a premium in peak seasons, when it is important to harvest and process one crop quickly so that the next one can be planted without delay. Both draft power and human labor become scarce under these conditions. For many operations draft power is a more critical constraint than human labor, so shortage of draft animal power may stimulate mechanization more than shortage of human labor (Day and Singh 1977; Roumasset and Smith 1981, David et al. 1994). Wage increases and draft power shortages need not apply throughout the year to induce mechanization, just during the period in which the operation takes place.

In principle, mechanization is a logical response to rising wages and will only take root in an economy with rising wages and substantial employment opportunities. Mechanization can proceed selectively by operation, crop and location; typically it begins for operations that are power-intensive (such as plowing or threshing) rather than precision-intensive (such as seeding or transplanting) (Pingali et al. 1997). As shown by Binswanger (1978) and Pingali et al. (1997), for many operations mechanization does not increase farmers' yields but simply substitutes for labor. The choice between machines and labor for such operations comes down to relative price differences. For other operations, such as threshing, mechanization can also bring efficiency increases. For example, mechanical threshing reduces breakage and thus raises the value (if not the quantity) of the output.

If this is so, then in the absence of economic policies that encourage mechanization, machines should not be considered a threat to workers. Pingali et al. (1997) argue that mechanization in Southeast Asia has taken place in response to rising wages and growing employment opportunities for farmers; it has enabled farmers to keep costs down but has not caused unemployment.

Day and Singh (1977), on the other hand, found that the Green Revolution in the Indian Punjab led to a major restructuring of the seasonal demand for labor. Although labor remained in surplus during most of the year, there were acute shortages during the peak planting and harvest seasons due to large increases in output. Draft power shortages were even more significant, and together these factors led to increasing demand for mechanical power, which in turn decreased the demand for labor. Day and Singh concluded that the overall effect was a reduction in labor demand. They emphasized that mechanization was an unexpected result of the Green Revolution, which many had hoped would alleviate unemployment in developing countries. They suggested that previous perceptions of labor surplus were mistaken and came mainly from failure to understand the importance of seasonal variation in demand.

Day and Singh recommended the introduction of improved fodder sources to reduce the cost of draft power, but evidence shows that the combination of cheaper fodder and more commercialization will promote dairy farming, not draft power. Dairy farming can be very lucrative for small farmers and it is highly employment intensive, but it is inconsistent with draft power because draft work reduces milk yields significantly (Soliman 1983). This suggests that perhaps mechanization is ultimately an inevitable outcome of commercial, irrigated agriculture.

MECHANIZATION AND ECONOMIC POLICY

One point on which everyone agrees is that government subsidies on machines cause employment to fall unnecessarily. This happened in Punjab and contributed to the labor displacement problems Day and Singh (1977) described. In Egypt in the 1980s, machines were subsidized through numerous channels: direct subsidies on tractors were combined with subsidies on foreign exchange and credit with which to purchase them and diesel fuel to operate them. The credit subsidy reduced machine cost by about 15 percent and the foreign exchange subsidy by about 46 percent, while the diesel subsidy reduced operating costs by about 30 percent (Cuddihy 1983). These policies undoubtedly displaced workers.

Mechanization in Egypt began initially with plowing, for which draft power was a real constraint. The stock of tractors with substantial excess capacity soon made it economical to mechanize other operations, especially since attachments such as tractor-powered threshers were inexpensive compared to tractors (Kerr 1990). In sum, tractor subsidies targeted to plowing led to rapid mechanization of other activities. Thanks to the multiple-use nature and long life span of tractors, subsidizing them can lead to much more labor displacement than expected, with little prospect of reversal once the machines are in place. Under these circumstances the negative impact on labor households can be substantial.

AGRICULTURAL RESEARCH AND MECHANIZATION

Research on agricultural mechanization is mainly a private sector activity because the returns can easily be captured privately as long as good patent protection is in place. One potentially useful role for the public sector is to try to develop appropriate machines that help reduce farmers' production constraints during a specific peak period while displacing as little labor as possible. The idea is to pre-empt the adoption of tractors, which will displace many more people. IRRI has conducted such research to encourage adoption of small machines (IRRI 1986). Experience with such research is mixed, with some cases of successful introduction of small-scale machines and others of failure to do so.

7. FOOD PRICES AND ACCESSIBILITY

Agricultural research can raise food availability and reduce prices to consumers through two channels: development of new agricultural technologies that lead to higher productivity, and social science research to identify technology priorities and devise policies that help poor people gain access to food.

This chapter begins by documenting rising demand for food in developing countries and then it suggests alternate ways to meet that demand. These include raising food production either by increasing cultivated area or by increasing yields, or else importing food from abroad. Evidence is presented on the role of both science and social science research in generating technology used to raise the food supply, and the effects on food prices and accessibility are discussed. The alternate approach of raising food imports is also discussed, along with its economic and political implications. Finally, social science research to help the poorest people gain access to food is discussed.

DEMAND AND SUPPLY OF FOOD IN DEVELOPING COUNTRIES

Demand

It is well known that food demand in developing countries has grown rapidly in recent decades, and that population growth has been the main force behind this increase. For example, the population of developing countries in Asia, home to about three-quarters of the world's poorest people, more than doubled from about 1.6 billion in 1961 to 3.3 billion in 1997 (FAO 1999). Food consumption was already perilously low in the 1960s with significant proportions of the population receiving an inadequate diet; some countries were highly susceptible to widespread famine. Prospects for raising the supply of food to keep up with anticipated population growth were grim. A 1967 prediction from a respected professor at Stanford University sums up commonly held fears at the time: "In the 1970s and 1980s hundreds of millions of people will starve to death in spite of any crash programs embarked on now" (Ehrlich 1967, cited by Tribe 1987).

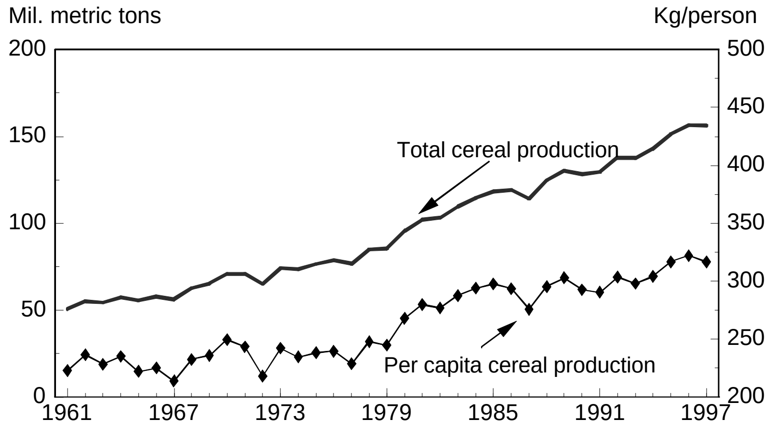
Supply

Despite the legitimate fears of food shortages expressed in the 1960s, the rapid growth in production documented in Chapter 3 has enabled most of the developing world to produce enough food for its people. Figures 7.1a-d show changes in total and per capita cereal production from 1961 to 1997 in China, Southeast Asia, South Asia and Sub-Saharan Africa. All of these figures demonstrate the very high increases in total food production discussed in Chapter 3, but they also demonstrate the important role of population growth in translating increased food production into continued low domestic food availability per capita. In China and Southeast Asia, where food production has burgeoned while population growth has slowed, per capita cereal production also rose significantly. Cereal production roughly tripled in South Asia, but production per capita rose only very slowly and remains at less than 300 kg. In Africa, meanwhile, total cereal production rose about two-and-a-half times but fell in per capita terms to the abysmally low level of around 125 kg. Incomes stagnated and nutrition status decreased on the whole; climatic, political and economic forces combined to bring famine and starvation in particularly bad years in some countries. Major shortfalls in agricultural production were met with food aid.

Countries can raise their food supply in four ways. The first two involve raising domestic food production, but this can be either by increasing the area under production or raising yields on existing area. The third is to import food commercially, and the fourth is through food aid.

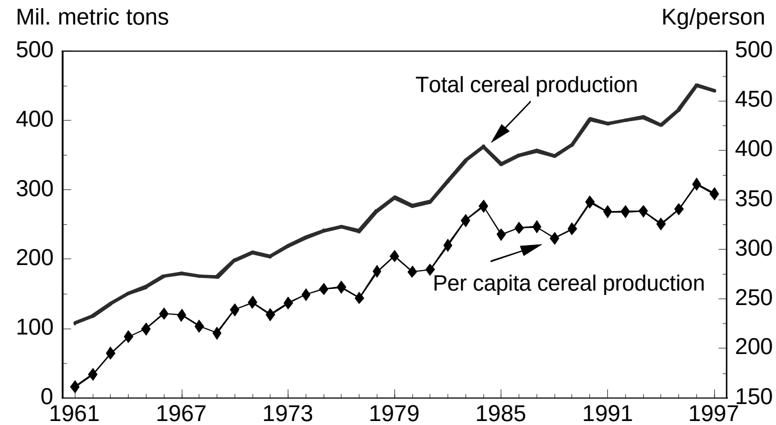
Asia in the 1960s relied on all of these measures to meet its growing food demands. However, due to the already high population density there was little room for expansion of land under agriculture. The most productive areas had already been exploited, so cultivating the lower potential areas remaining would not have raised food output in proportion to the additional area covered. In India in the 1950s and 1960s, most of the increase in productivity came from expansion of area along with expansion of irrigation, which raised yields (Vaidyanathan 1993; Hanumantha Rao 1994). But there was too

Figure 7.1a: Growth of cereal production in China.



Source: FAO.

Figure 7.1b: Growth of cereal production in Southeast Asia.

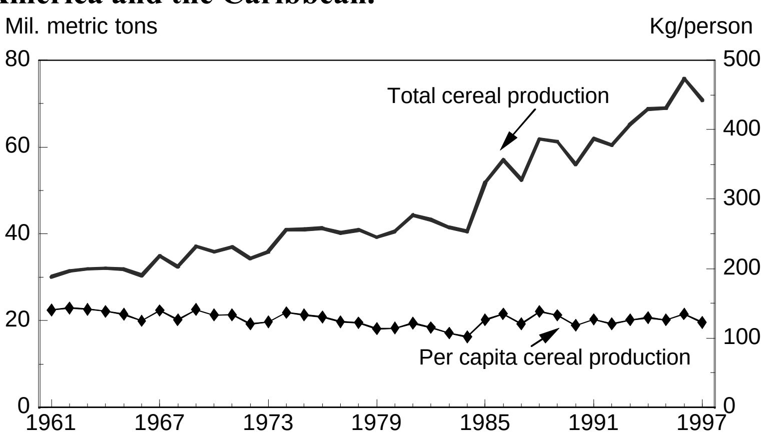


Source: FAO.

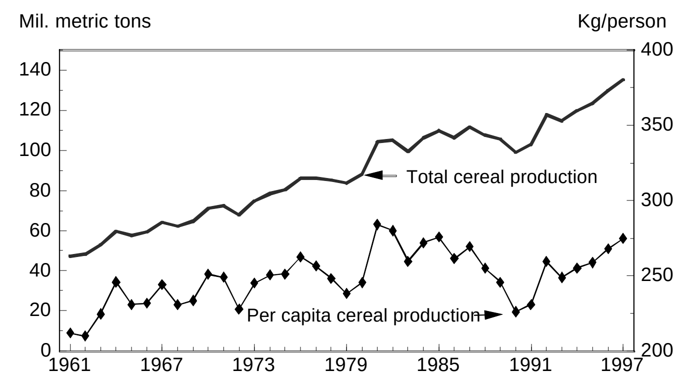
Figure 7.1c: Growth of cereal production in Sub-Saharan Africa.

Figure 7.1d: Growth of cereal production in Latin

America and the Caribbean.

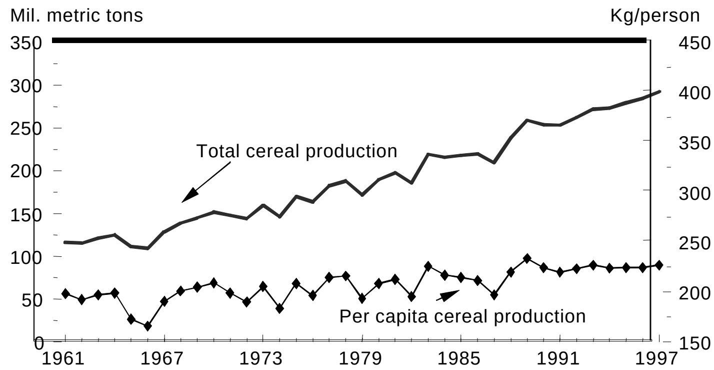


Source: FAO.



Source: FAO.

Figure 7.1e: Growth of cereal production in South Asia.



little scope to expand irrigation by enough to meet predicted food needs. Also in the 1960s, India was a food importer and one of the largest recipients of American food aid under the PL 480 program. This was a major source of political concern in India, especially when the United States attempted to use its food aid as leverage to encourage changes in Indian agricultural policies (Subramanian 1979, cited by Abler et al. 1994). Other densely populated Asian countries faced similar concerns.

Some examples of the impressive food production outcomes of the last few decades are as follows:

- In China, grain production grew by almost 50 percent between 1978 and 1992; in per capita terms the increase was over 20 percent (Chunming 1996). Food consumption during the period also increased; grain consumption was roughly stable from 1984 onward at a relatively high level of 250 kg per capita per year, and per capita consumption of meat, poultry, eggs and fish all rose by 3-5 kg per year. The percentage of people consuming inadequate diets fell steadily during the period.
- Per capita cereal grain production also grew in Southeast Asia, as mentioned above for the case of rice. Every country in the region experienced improved nutritional status during the 1970s and 1980s

(Tontisirin and Winichagoon 1996). Indonesia was well known as the world's largest rice importer in the 1970s at a peak cost of 25 percent of its foreign exchange. Rice imports began to decline in 1974 as production grew thanks to both accesses to new technology and favorable producer prices. By the 1980s the country had achieved self-sufficiency, and since then the country has become a net exporter, selling a variety of agricultural products.

- In Haiti, an NGO called Organization for Rehabilitation of the Environment (ORE) identified, multiplied and distributed improved mango and avocado trees. Although these are cash crops consumed by wealthy people in most countries, in Haiti they are an important source of food for the poorest people during periods when other foods are in short supply. The grafted trees give much higher fruit yields, thus offering important food security benefits. Some of the introduced species yield fruit in the off-season, further raising food availability. Even though the fruit are targeted to the commercial market, a large number do not meet quality standards and so poor people consume them. ORE has distributed about 120,000 grafted trees since 1985 and stimulated similar work by the government and other NGOs. About 15 percent of all mango and avocado trees in Haiti are now improved through grafting (ORE 1998; Alex Bellande, pers comm.).

PRICE IMPACTS OF INCREASED PRODUCTION

The effect of increased production on food prices depends on several factors. In theory, if food demand rises in a closed economy there will be pressure on food prices to increase as in Figure 7.2a. If demand is constant and food supply rises, on the other hand, the pressure on food prices will be downward as in Figure 7.2b. If the economy is open and the country is too small to have a noticeable effect on world trade, then supply is considered perfectly elastic and changes in demand will have no effect on prices as in Figure 7.2c. If the country carries a large enough weight in world markets, on the other hand, then the effect of local demand will resemble that in the closed economy case. Higher demand will raise prices (as in Figure 7.2a) and higher supply will reduce prices (as in Figure 7.2b). In the context of the need to feed the world's growing population, rising food supply helps avoid the upward price pressure resulting from growing demand.

Figure 7.2a: Shift in food demand with no technological improvement in a closed economy.

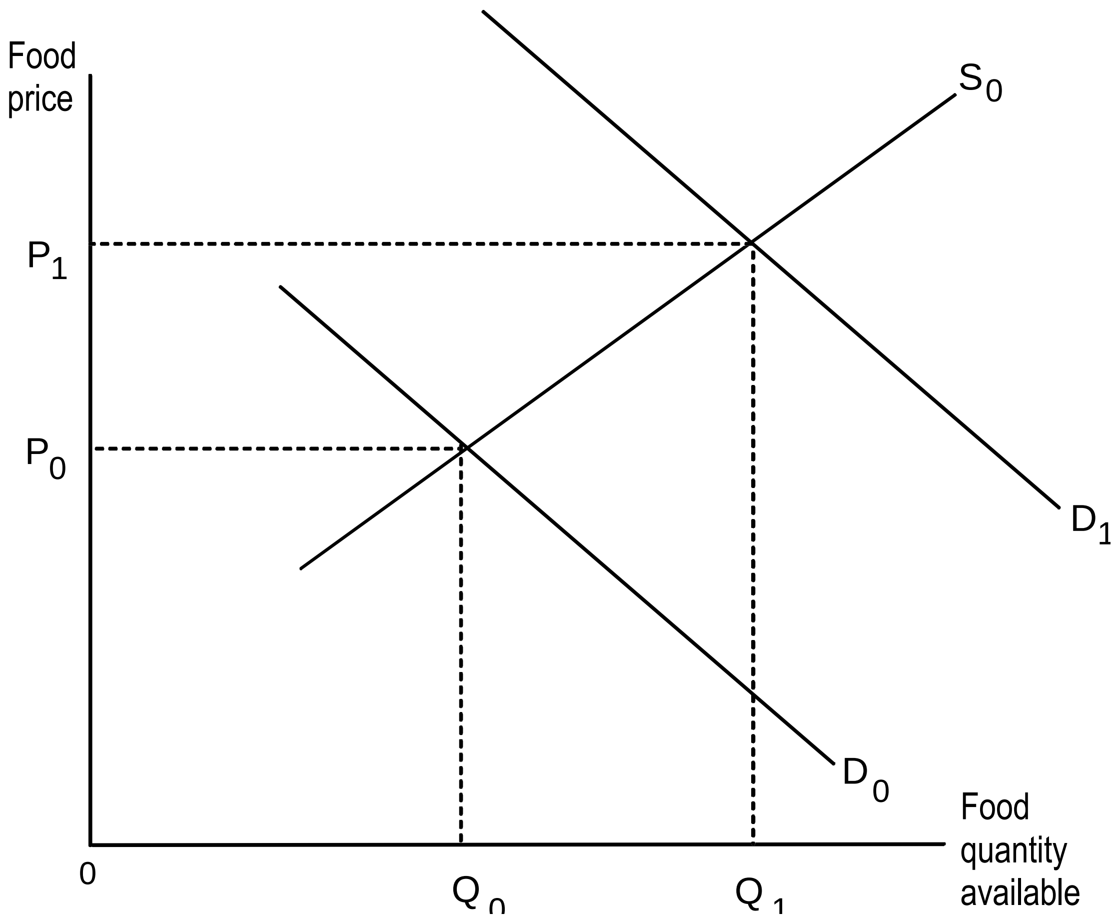


Figure 7.2b: Food supply shift causes price reduction if demand does not shift.

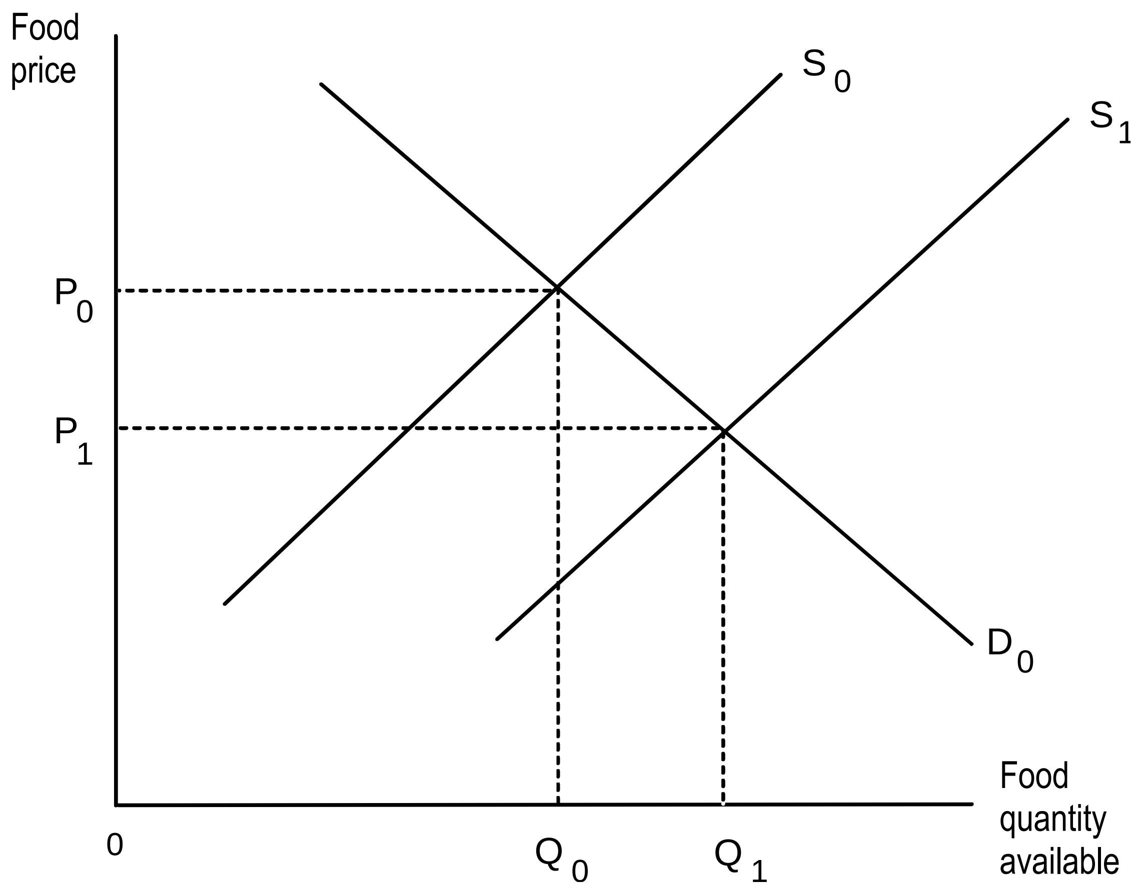
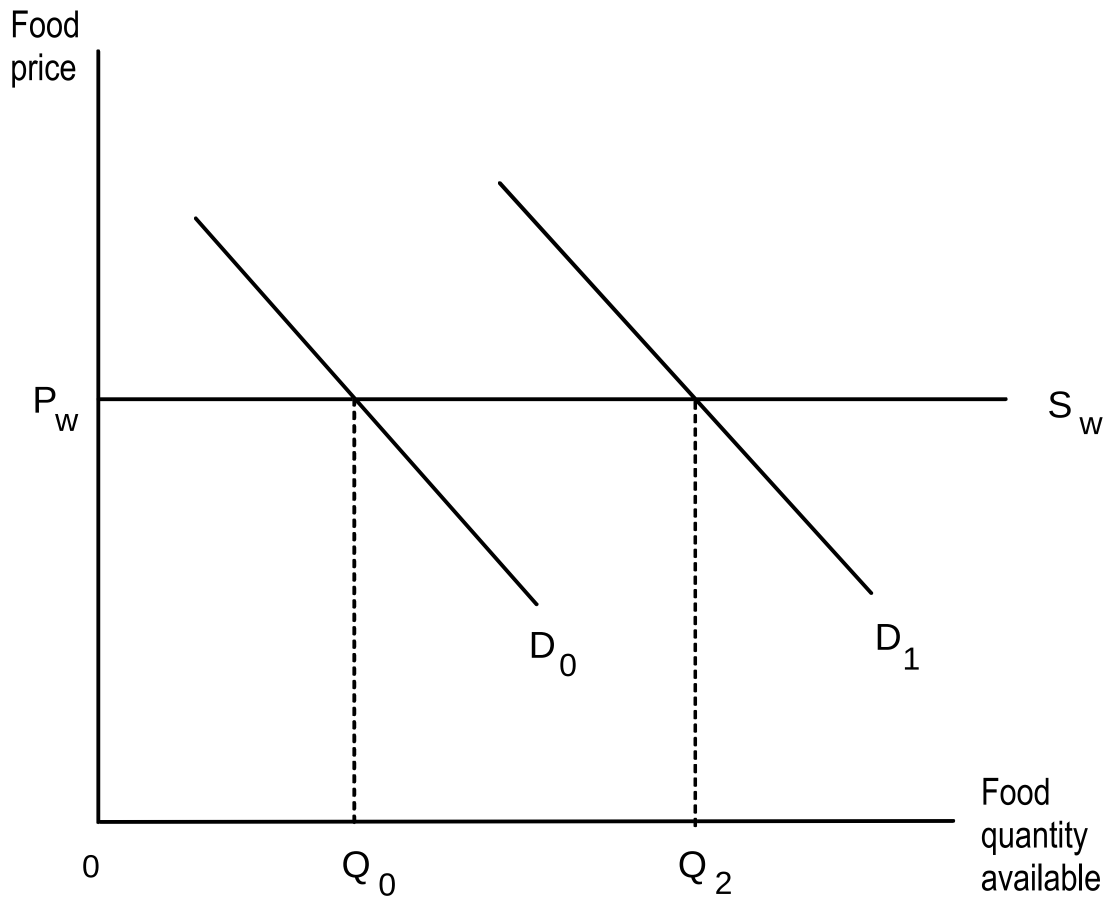


Figure 7.2c: Food demand shift has no price effect for a small, open economy.



All consumers have equal access to benefits from lower food prices, but poor people who devote the largest proportion of their incomes to basic food grains benefit the most in practice (Anderson et al. 1988b; Lipton 1989). The poorest consumers in developing countries can spend as much as 80 percent of their income on food (Uvin 1998). For such a person, a 3 percent drop in the price of wheat would raise the amount of their total income available for other purchases by more than 10 percent, assuming they continued to buy the same quantity of wheat.

In most developing countries the poorest farmers with the smallest holdings may buy more food than they sell, so they benefit from falling prices as well. Where poor people produce as much or more than they sell, effects on them of lower prices will depend on several factors that are discussed in Chapter 6.[8]

In the real world, many governments intervene in food markets to keep consumer food prices stable, so the relationship between supply, demand and prices is not always visible. As a result, evidence about the relationship between increased production and consumer prices is often somewhat indirect.

Another important determinant of consumer prices is the economic and technical efficiency of the marketing system, including transport, processing and storage.

Economic efficiency in this context refers to competitiveness. If marketing is competitive, lower food prices paid to producers will be passed on to consumers while prices paid for marketing will not change much. But if marketing is not competitive, marketers could expand the margin between the price they pay to farmers and the price they charge to consumers. Technical inefficiency can reduce the price benefit to consumers through another mechanism: high costs due to food spoilage or slow movement from farm to market that ties up costly capital can significantly raise the margin between producer and consumer prices, even if the marketing sector is competitive. The higher the proportion of consumer prices embodied in marketing, the smaller the effect on consumer prices of lower producer prices. A simple example makes the point. Imagine that in economy A, the producer price is $10/unit and the marketing cost is another $10/unit, making the consumer price $20/unit. If the producer price falls by 10 percent to $9/unit, the consumer price will fall by 5 percent to $19/unit. Next consider economy B, where the $20/unit consumer price embodies a $5/unit producer price and a $15/unit marketing cost. In this case a 10 percent reduction in the producer price (to $4.50/unit) will only reduce the consumer price by 2.5 percent, to $19.50/unit.

The following examples give an idea of the price effects of rising food production:

- In Punjab, India, where research-led technology change raised production greatly, prices paid to producers fell more than 3 percent

[8] As explained in Chapter 6, falling prices do not imply losses to producers if technical advances enable them to reduce their costs of production (Pinstrup Anderson and Hazell 1985: 12).

annually between 1968 and 1989 (Byerlee and Moya 1993). Although consumers may not have noticed the change due to government interventions, rising food supply reduced the government's cost of intervening in the market. Production costs fell by even more, so farmers continued to make a profit (Figure 7.3).

- In the Philippines, Warr and Coxhead (1993) found that technical change brought higher productivity and lower prices for the foods that poor people consume the most of. The poorest quintile of the population effectively gained the greatest income gains due to a major reduction in their food expenditures. Quizon and Binswanger (1986) also found that rural laborers gained greatly through reduced food prices.
- In the study of Pakistan by Renkow (1993), mentioned above, government price controls limited the impact of rising wheat output on prices. In a simulation analysis in which prices were determined by supply and demand, on the other hand, wheat prices fell sharply with higher output and wheat consumers benefited greatly.

The price benefits of improved food production technology come from additional sources besides increased output. For example, as discussed in Chapter 3, characteristics of modern varieties such as reduced susceptibility to pests and diseases can be expected to reduce yield variability. Also mentioned in Chapter 3, many new varieties have a shorter duration than traditional cultivars, enabling double cropping that results in a more even flow of food supply (Anderson et al. 1988b). This may reduce price swings that can strain the budgets of poor people in lean seasons, or else those of governments that buy and sell grain in order to stabilize prices. Alauddin and Tisdell (1988) found empirical evidence of increased stability in Bangladesh.[9]

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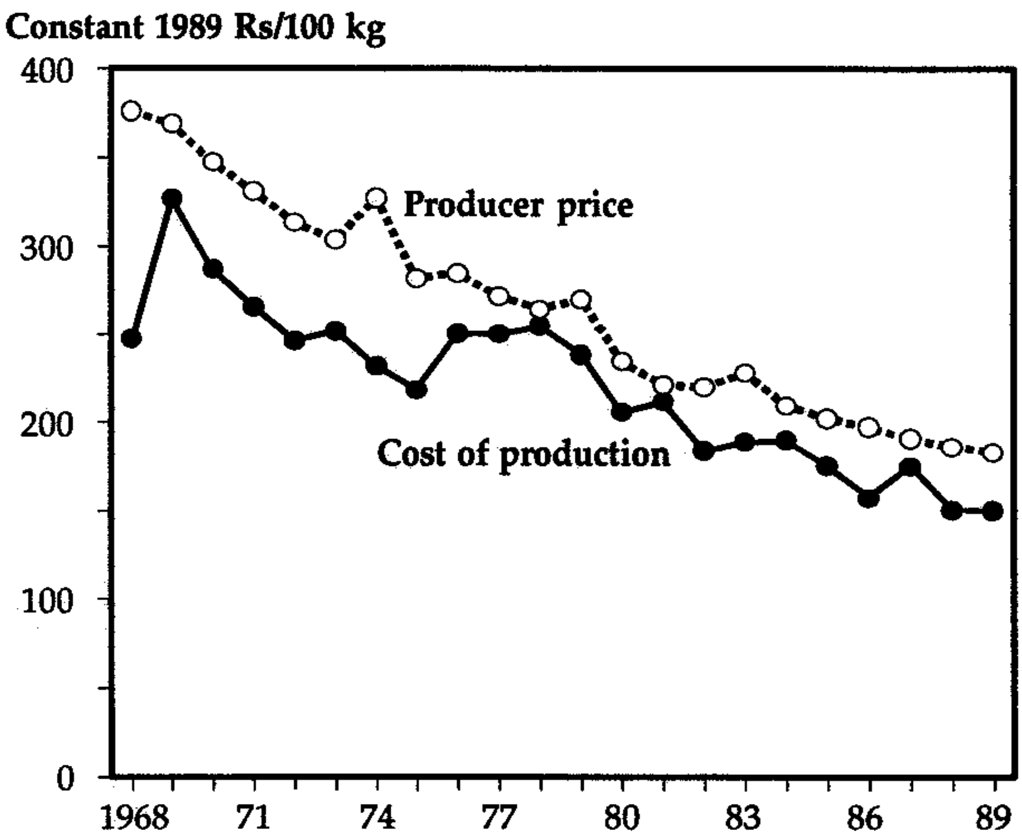
[9] Hazell and Ramasamy (1991), on the other hand, found higher instability with the green revolution in rice in Tamil Nadu, India, but this was a result of the unpredictable nature of tank irrigation rather than the modern varieties. Performance of

Figure 7.3: Relationship between producer price and cost of production as output increased in Punjab, India.



Whereas modern varieties played a critical role in raising food output, this did not always translate into improved diets for all. In India, for example, hundreds of millions of poor people still consume a sub-standard diet despite aggregate improvements and a more stable food supply. In Bangladesh, meanwhile, modern rice varieties have made it possible for more people to survive whereas at independence in 1971 there were very real doubts about the prospects for avoiding starvation. Nonetheless, Alauddin and Tisdell (1991) found that even though rice, the dominant staple, maintained a constant real price and per capita supply during the period 1967-1984, the average diet worsened because the

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irrigation tanks in south India has declined in recent years, with highly fluctuating water supply (Palanisamy and Flinn 1989).

per capita availability of vegetables, pulses, fruits and spices all fell between 18 and 50 percent. Only potatoes fell in price, both in absolute terms and relative to the price of rice. As a result, the average citizen consumed a narrower, less nutritious diet in 1984 than in 1967. Other studies of Bangladesh (e.g. Khan 1990) show similar results.

The study by Abler et al. (1994) questions the role of domestic food production increases in raising food supply and reducing prices to help impoverished consumers. In their study of Indian agriculture they point out that grain prices have been stable since the 1960s. This leads them to argue that technological improvements that shift the domestic agricultural supply curve (i.e. increase supply at any given price) do not significantly affect domestic prices. Further, they argue that foreign excess supply is highly elastic, meaning that international grain markets can respond quickly to export opportunities, and that India is not a large enough importer of grain to affect world prices. As a result, they propose that India could have maintained the same level of agricultural commodity prices had there been no green revolution and India had relied on imported sources of grain. The major contribution of the green revolution, they suggest, may have been the political benefits of food self-sufficiency mentioned above.

Abler et al.'s conclusion may be valid from the narrow perspective of a formal economic model focusing on long run relationships. In the real world, however, several factors not mentioned by the authors must be considered, as follows:

- In a long run model year-to-year international price fluctuations may be unimportant, whereas in reality they can be costly either for individual consumers or governments trying to cushion price shocks through market interventions. Most large developing countries would strive to avoid Indonesia's experience in the rice market, referred to above.
- Even if it were true that India could import food without affecting long term prices, without the green revolution not just India but also the rest of Asia would rely on world trade, putting much more strain on international suppliers and making all of them more vulnerable to trade shocks.

- Even with relatively low-priced, stable supplies of imported food, a vast number of Asian farm families would be less food-secure in the absence of high yielding varieties. This is because so many farm households cultivate tiny plots that yield barely enough to feed the family. Such households would be even more vulnerable to malnutrition if their land produced less food and they had to rely even more on markets.

An important issue related to this last point concerns the gap between domestic and international prices under contrasting circumstances. In particular, for a large, rural country with poor infrastructure and many small producers, the local market price may be very different from the international price. Locally produced crops will be much cheaper and imported crops much more expensive. The cost of delivering food to small villages in the interior of Sub-Saharan Africa or even India may be much lower if it is produced locally rather than imported.

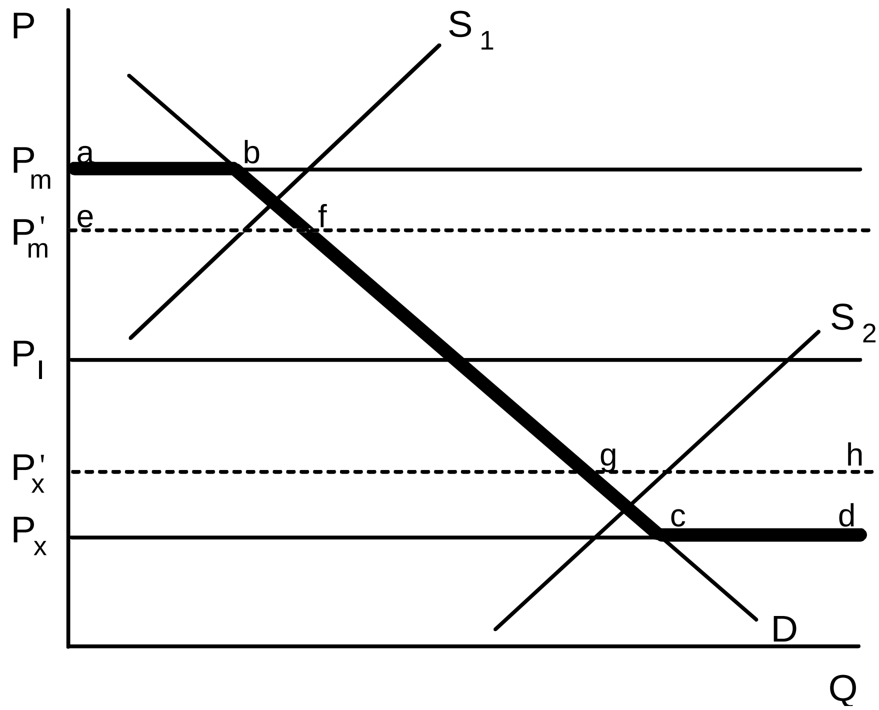
The reason for this can be explained as follows. The international price of food is measured as the price at the international port or border before it has been unloaded for import or after it has been loaded for export. Before consumers can access imported food they must pay the costs of unloading, storing and marketing. As a result, consumer prices for imported food exceed the international price by the amount of these costs. Export crop prices work the same but in reverse: farm gate prices (received by producers) must be less than the border price by the cost of marketing and loading. All of this means that there can be a broad price range in between a commodity's border price and what consumers actually pay for it. This broad range is depicted in Figure 7.4, where P_I is the international price, P_X is the farm gate price for exportables, and P_M is the market price for importables. A country will neither import nor export if its production costs lie anywhere between P_X and P_M. In this case the demand curve becomes the staggered line *abcd*, traced in bold in Figure 7.4. If domestic supply is represented by S_1, there will be no imports nor exports, and price and quantity will be determined at the intersection of S_1 and D. An analogous situation holds if domestic supply is represented by S_2. S_1 and S_2

both intersect D within the self-sufficiency price range, so there are no imports and no exports.

Whereas a large rural country with poor infrastructure may enjoy price benefits from self-sufficiency, an urban country with good infrastructure will not. Urbanization and improved infrastructure can be expected to reduce the range between P_X and P_M. Improved infrastructure reduces marketing costs between the port and all consumers, and urbanization reduces the cost of importables because there are scale economies in delivering food where consumers are concentrated in one place. For port cities the cost of distributing imported food can be particularly low. In Figure 7.4, falling marketing costs reduce the range to P'_X P'_M, and the domestic demand curve is the staggered line *efgh*. In this case, where domestic supply is represented by S1 the country will become an importer, since the cost of domestic production exceeds the sum of the international price plus marketing costs. Similarly, if domestic supply is represented by S^2, the country can become an exporter, because the sum of domestic production price plus marketing costs is still less than the international price.

A declining range between importable and exportable prices may have important implications for developing countries because, as discussed in Chapter 2, they are becoming increasingly urban (see Table 2.2). Latin America is already about 75 percent urban. Infrastructure is also improving in most countries. As a result, the food price advantage of self-sufficiency is smaller than it was in the past, and it will continue to decline gradually over time.

Figure 7.4: International prices, domestic prices, imports and exports.



SOCIOECONOMIC AND POLICY RESEARCH

As mentioned above, agricultural research includes not only technical research but also analysis of socioeconomic and policy issues. Some economic research contributes to decision-making related to scientific research and thus contributes to technology development. Research related to economic policy can identify mechanisms to help the poorest people increase their access to food, for example through targeted food subsidies or income generation programs.

An example of the former concerns socioeconomic research at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in the 1970s to guide crop breeding strategies to meet human nutrition objectives (Walker and Ryan 1990). At the time it was believed that protein and lysine deficiencies were the greatest nutritional threat to poor households; some breeding programs aimed to raise the content of these nutrients in food grains. This was not an easy scientific objective as tradeoffs emerged between breeding for nutrient content and breeding for high yield. Add to this the particular difficulties of developing adoptable varieties in semi-arid tropical areas, and the value of choosing the right breeding strategy becomes very high.

ICRISAT social science researchers conducted two sets of studies that helped them provide unequivocal recommendations to crop breeders about which breeding objective to pursue. First, Ryan (1976) found that energy deficiency was the greatest constraint to poor households with low consumption levels in several SAT regions. This meant that simply increasing their food intake was more important than increasing the protein or lysine content of their diet. Second, ICRISAT researchers used data on food budget shares and price elasticities for different commodities and income groups to estimate 1) how much the price of each commodity would fall if supply were to rise by 10 percent and 2) how much additional food quantity households would be expected to purchase under the estimated price decline. They used these estimates in turn to calculate the additional nutrient intake associated with the higher consumption. The findings showed unequivocally that raising food supplies through higher yields offered by far the greatest benefits to poor households, and this helped guide the objectives of crop breeding programs all over the world.

Policy analysis is another type of social science research related to agriculture and food. It need not be related directly to agricultural experimentation or research prioritization. Policy analysis related to food price and accessibility involves designing approaches to help poor people gain increased access to food. The key challenge in such policy research is to find ways to ways to target nonmarket transfer so that they reach the maximum number of poor people, have the minimum amount of spillover to the nonpoor, and have minimum impact on food prices in order to avoid distortions to farmers' incentives.

8. LINKAGES BETWEEN AGRICULTURAL TECHNOLOGY, ECONOMIC GROWTH AND POVERTY ALLEVIATION

Agricultural production is the primary source of rural employment in many developing countries, but another very important employment source is the nonfarm sector, which includes services, trade and industry that serve agriculture and rural consumers. The fact that so much of the nonfarm sector is linked to agriculture suggests the possibility that agricultural output could trigger additional growth in other sectors of the economy, raising employment and incomes. This is an area of strong debate in the literature that focuses on two questions:

- Does technology-led agricultural productivity growth lead to widespread economic growth?
- Does economic growth lead to reduction in the number of poor people?

This chapter summarizes that debate and presents some of the evidence. It also spells out some economic and policy conditions that determine the answers to these questions.

THE ROLE OF AGRICULTURAL GROWTH IN STIMULATING WIDER ECONOMIC GROWTH

Hazell and Haggblade (1993) set the stage for analysis of growth linkages by pointing out the relatively high percentage of rural workers throughout the developing world who are engaged primarily in nonagricultural employment. Table 8.1 shows that this number is higher in Asia and Latin America than Africa, and that it rises considerably when rural towns are taken into account. Also, Table 8.2 shows that the share of household nonagricultural income is inversely related to farm size, with landless and near-landless workers deriving between a third and two-thirds of their income from off-farm sources. In other words, poorer farmers and laborers tend to depend more on nonagricultural income than wealthy farmers, so they stand to benefit from growth in this sector.

Analysis of linkages between economic sectors goes back to the 1950s according to Delgado et al. (1998). Early work focused on the "backward" and "forward" linkages in production. Backward linkages refer to the new demand for inputs used in a new production activity, while forward linkages refer to new processing industries stimulated by the availability of raw materials provided by the new production. The early literature (Hirschman 1958; Prebisch 1959) argued that agriculture had relatively weak backward and forward linkages in production, and this is one reason why early development theorists assumed that growth of industry rather than agriculture promised more rapid economic development. Subsequent analysis by Mellor (1966) and Adelman and Morris (1973) in the context of a closed economy revealed the point that while production linkages from agriculture may be small, consumption linkages may be quite large (Delgado et al. 1998). Another important point that emerged from more recent literature was that through linkages across sectors, growth in one sector could drive up wages in others, thus raising production costs and limiting the multiplier effect. For example, if agricultural production growth raises wages, there will be less scope for growth in labor intensive nonfarm industry and services (Delgado et al. 1998; Abler et al. 1994). Delgado et al., drawing on all the earlier literature, concluded that five interrelated factors determine the potential for growth linkages in agriculture:

1) Agriculture must be a large enough sector to generate significant growth through linkages to other sectors. The corollary is that if agriculture is a large sector it cannot be ignored.
2) Economic growth linkages will be higher if agricultural growth benefits are equitably distributed among the rural population, because new demand will come from a broad base of rural people with a high marginal propensity to consume low cost goods and services.

Table 8.1 Share of the rural labor force employed primarily in nonfarm activities, Africa, Asia, and Latin America, various years

Type of locality	Africa	Asia	Latin America
		(percent)	
Rural settlements [a]	14	26	28
Rural towns [b]	59	81	85
Rural settlements plus rural towns			
Total	19	36	47
Male [c]	16	37	36
Female [d]	19	34	79
		(Employment density per 1,000 population)	
Rural settlements [a]	50	83	79
Rural towns [b]	187	238	245
Rural settlements plus rural towns			
Total	65	121	129
Male [c]	35	90	87
Female [d]	30	31	42

Note: Includes all nonagricultural activity except mining--that is, International Standard Industrial Classification activities 3-9.

[a] Rural settlements vary in size with individual countries' census definitions. Generally, rural settlements in Africa and Asia are those with population less than 5,000. In Latin America, the cutoff is normally 2,000 or 2,500.

[b] Rural towns do not exceed 250,000 in population.

[c] Male nonfarm employment divided, for percentages, by total male employment; for densities, by total population.

[d] Female nonfarm employment divided, for percentages, by total female employment; for densities, by total population.

Source: Hazell and Haggblade 1993. Original source: Population censuses for forty three countries (fourteen in Africa, fourteen in Asia, and fifteen in Latin America); they include all those for which employment data could be broken out by locality, size of settlement, and sex. The censuses were conducted in various years during the 1960s, the 1970s, and the 1980s.

Table 8.2: Share of nonfarm income in total household income, by size of landholding, selected developing countries, various years

Country or region/year	Size of holding	Nonfarm income as a share of household income[a]
	(hectares)	(percent)
Korea, Republic of (1986)	0-0.5	73
	0.5-1.0	49
	1.0-1.5	35
	1.5-2.0	26
	2.0+	19
Taiwan (China) (1979)	0-0.5	67
	0.5-1.0	58
	1.0-1.5	48
	1.5-2.0	40
	2.0+	33
Ecuador (1974)	0-1.0	40
	1.0-2.0	22
	2.0-10.0	14
	10.0-100.0	10
	100+	9
India (1970-71)	landless	62
	0-1.0	34
	1.0-4.5	21
	4.5-10.5	11
	10.5+	3
North Arcot, India (1982-83)	0-0.1	35
	0.1-1.0	23
	1.0+	20
Northern Nigeria (1974)	0-0.99	55
	1.0-1.99	29
	2.0-2.99	24
	3.0-3.99	14
	4.0-4.99	17
	5.0+	26

[a] Nonfarm income was estimated by deducting agricultural wage income (1.8 percent of total earnings) from reported "off-farm" income.
Source: Hazell and Haggblade 1993.

3) The growth impact will be greater the higher the proportion of newly purchased goods that are nontradable, so that their production is constrained primarily by local demand (i.e. they cannot simply be purchased from outside of the local area or produced in the local area to be shipped elsewhere). Labor-intensive services "produced" in rural areas are nontradable and so are many simple products produced there, so they will have high growth linkages.
4) Demand for labor-intensive goods and services produced in rural areas is more likely with more equitably distributed income growth. If new income is highly concentrated among the wealthy, their purchases will include more high-valued products such as consumer durables and luxury goods that are produced in cities or abroad. In this case the rural nonfarm growth linkages will be smaller.
5) There must be a supply of underused local resources (such as unemployed labor) so that increased spending does not simply translate into higher prices, which would reduce the amount of goods and services purchased (and the amount of employment generated).

Hazell and Haggblade (1993) report several studies' estimates of agriculture's growth multipliers based on a variety of models. Excluding models with less realistic assumptions, they estimated multipliers ranging from 1.3 to 1.8, meaning that one dollar of agricultural growth would lead to increased nonfarm income ranging from $0.30 to $0.80. Hazell and Haggblade further refined the model and narrowed the range to about 1.37 to 1.54 for various regions of India. The multiplier for consumption was larger than that for production; consumption accounted for about 60-90 percent of the total multiplier. Various region-specific factors affected the multipliers; for example, higher road density raised the multiplier, as did higher input use in agriculture.

Delgado et al. (1998) applied a similar model to several countries in sub-Saharan Africa: Burkina Faso, Niger, Senegal, Zambia, and Zimbabwe. Their analysis revealed growth multipliers ranging from 1.96 to 2.88. If these average multipliers are disaggregated into those stemming from expenditures of different income terciles, expenditures from the poorest tercile have higher multipliers than those from the highest. This reflects the reasoning presented above that poor people will spend additional income on simpler products supplied locally.

Abler et al. (1994) drew very different conclusions in their study of India, arguing that agricultural growth competes with rather than stimulates the nonagricultural sector. In fact, they suggested that India’s current national income would not look much different had there been no green revolution; the level would be the same but industrial progress would have replaced much of the agricultural growth. The basis for this argument is that agricultural demand draws labor and capital away from industry, thus reducing industrial output; this implies labor supply inelasticity. This reasoning is consistent with the conditions cited by Delgado et al. (1998) that linkages require production based on an underused factor with elastic supply. However, the assumption of inelastic labor supply seems unrealistic given the high population of underemployed rural workers in India. Also, Delgado et al. and Hazell and Haggblade argued that most rural nonfarm economic activity is more labor intensive than capital intensive.

Other studies have drawn similar conclusions to Hazell and Haggblade and Delgado et al. Warr and Coxhead (1993) used a CGE model and found that technical change in agriculture accounted for 30 percent of the 2.8 percent annual overall economic growth in the Philippines. De Janvry and Sadoulet (1993) found agriculture to be the main engine of economic growth in Latin America.

POVERTY IMPACT OF AGRICULTURAL GROWTH

If research-led agricultural productivity growth stimulates economic growth, the question remains whether this growth helps poor people. This is a topic of major debate resulting from the fact that observations from around the world reveal examples of both situations: those in which economic growth reduced poverty and those where it did not. There have also been cases in which poverty increases while the economy grows. In addition, even in cases when poverty declines in the aggregate, some people may become worse off when overall economic growth leads to structural economic changes in which some sectors decline. Lipton and van der Gaag (1993) cite several examples of cases in which economic growth did not necessarily bring poverty alleviation; these include Brazil in the 1980s, Pakistan in the 1960s, and the United States in the 1970s. Clearly economic growth is not the sole determinant of poverty alleviation. This section reviews the evidence on the relationship between growth and poverty alleviation and spells out some additional necessary conditions for poverty alleviation.

Three recent analyses based on multiple country data examined the relationship between economic growth and poverty alleviation. Ravallion (1995) used data from 36 developing countries, representing 78 percent of the population of the developing world, to assess the growth-poverty link during the 1980s. The data revealed a strong negative association between per capita income and the percentage of people in poverty. There was no evidence, on the other hand, that economic growth either increased or reduced the distribution of income, suggesting that, on the whole, proportional increases in income were evenly spread. At the same time, Ravallion cautioned that the econometric analysis left "a sizable unexplained variation in country performance at reducing poverty for a given rate of growth." In other words, clearly other factors matter too.

Deininger and Squire (1996) conducted a similar analysis using a much larger data set of 680 high quality observations for different countries and years. By high quality, they mean that 1) the unit of observation was the household or individual; 2) the sample reflected comprehensive coverage of the entire population, and 3) the data provided a comprehensive measurement of income or expenditure. The years covered ranged from the 1950s to the 1990s, with a high proportion in the 1990s. Their results for both poverty alleviation and income distribution were very similar to Ravallion's. In the 95 cases of economic growth covered by their data, over 85 percent were accompanied by an increase in the incomes of the poorest quintile of the population. Changes in income distribution varied widely; in half the cases it became more equal while in half it became less equal.

Smith and Haddad (1999) undertook a similar study but their measure of poverty was the percentage of children who are malnourished, not the percentage of people below the poverty line. They sought to explain the determinants of changing levels of child malnutrition between 1970 and 1995 in 63 countries, representing 88 percent of the developing world's population. The full sample of countries doubled its national income between 1970 and 1995 and this contributed a 7.4 percent reduction in child malnutrition. Other factors were also extremely important, particularly women's education, improvements in the environment, and increases in food availability.

The comprehensive evidence presented by Ravallion (1995), Deininger and Squire (1996), and Smith and Haddad (1999) offers four clear implications:

1) Economic growth is not sufficient for poverty reduction, but it is necessary.
2) There is a need for greater understanding of the conditions under which economic growth leads to poverty alleviation.
3) There is no simple relationship between growth and the distribution of income—often distribution becomes less equal even while the poorest are becoming wealthier. This is consistent with evidence from Chapter 6 that even when wages rise absolutely, they may rise less than the returns to other factors of production. Poverty reduction with inequitable distribution of income remains problematic if it means that the poorest people move slightly above the poverty line (but remain very poor by reasonable standards) while wealthier people grow far wealthier. Unequal power relations will only be reinforced and many of the nonmonetary measures of poverty will have gone unchecked.
4) Poverty alleviation requires other actions besides just promoting economic growth.

What characteristics of growing economies are likely to encourage poverty reduction? Ravallion and Datt (1994) found that rural economic growth in India between 1951 and 1991 had a greater poverty alleviation impact than urban growth in India. Rural growth had sizeable beneficial impacts on both rural and urban poverty alleviation, whereas urban growth had little effect on urban poverty and virtually none on rural poverty. Landell-Mills (1996), meanwhile, attributed Indonesia's superior performance in poverty reduction to the more equal initial distribution of pre-growth income. Other authors agree that this is important but stress that it is not enough (Reutlinger 1996; World Bank 1990). Hazell and Haggblade (1993) added another dimension: to achieve broad-based agricultural productivity growth with substantial linkages to labor-intensive nonfarm development, there must be equitable distribution not only of initial assets but also access to social services and infrastructure.

Hazell and Haggblade (1993) suggested several steps that can be taken to promote growth with poverty alleviation and equity:

- In many countries, promoting nonfarm rural economic growth requires removing discrimination in investment codes against small, nonfarm firms.
- Rural towns, not dispersed settlements and small villages, are the focal point of nonfarm growth. They need to be supported with improved physical and infrastructure and better services such as credit. Balanced agricultural growth also requires equitable investment in infrastructure and distribution of services such as credit and extension to reach all farmers regardless of poverty status, social class, gender, etc.
- In addition to infrastructure and services, there is a need to invest in human capital, such as education, health and nutrition, to enable people to realize their own potential productivity. Such investments also must be widely targeted so that everyone benefits from them. Lipton and van der Gaag (1993) stressed that health, nutrition and education investments are complementary, i.e. a person well endowed with all three will be far better off than another with any two of them. He also argued that it is important to allow the private sector to provide health care and education in order to make sure public sector-provided education and health services are not in short supply and thus rationed to the rich.
- Data suggest that commerce and services are the most important growth sectors in the nonfarm rural economy, but assistance programs typically focus on the manufacturing sector, which may be much less important. Women operate many of these commerce and service businesses and it is important that support services be targeted to them.

- Highly skewed landholding distribution may prevent broad-based agricultural growth. Land reforms have often failed in the past because powerful landholders resisted appropriation of their assets. This suggests that successful land reform would require compensating the landlords for the fair value of the land. Given the evidence suggesting this approach could pay for itself over time (Lipton and van der Gaag 1993).

Even if such approaches are encouraged to make growth conducive to poverty alleviation, it is important to remember that economic growth takes time. Even if it helps poor people over time, they will need other measures to help them today. Reutlinger (1996), meanwhile, stresses that any poverty alleviation strategy worth the name will require tradeoffs with economic growth. There can be no illusions that a sole focus on economic growth will solve the problems of all poor people.

With this in mind, the World Bank (1990) recommended a three-pronged approach to poverty alleviation based on labor-intensive economic growth, provision of basic social services to the poor, and a program of well-targeted transfers and safety nets to protect the poor. This approach calls for special poverty alleviation programs targeted to meet poor people's needs. As discussed in Chapter 7, targeting is important to ensure that such efforts reach their intended beneficiaries with minimum spillovers to non-poor people. While an adequate discussion of poverty alleviation programs is not possible here, mention can be made of a few of the wide variety of poverty alleviation approaches that have been tried around the world:

- Targeted food programs such as those mentioned in Chapter 7.
- Provision of productive assets, such as land, irrigation, dairy cattle, agricultural implements and inputs, to poor people.
- Employment guarantee programs that ensure poor people the ability to earn income. If employment programs offer wages slightly below those offered in the casual labor market, they will be self-targeted to the poorest laborers who have more difficulty attracting private employment. Evidence suggests that this approach has been very

effective in providing assistance to poor people with low leakage (Datt and Ravallion 1993; von Braun 1995).

- Integrated approaches that try to address numerous problems simultaneously. For example, public employment can be directed to create productive assets, such as infrastructure, that can stimulate economic growth. However, evidence suggests that while the employment benefit is undeniable, often the assets created through such work are of low quality and may not contribute much to long term growth (Jackson 1982; Kerr et al. 1999). Some programs, such as India's Integrated Rural Development Program, undertake a wide variety of development activities all linked to each other. Experience suggests that this approach can cause overwhelming administrative problems that lead to ineffectiveness and waste.

In summary, the bottom line of this chapter is that rural economic growth is a critical contributor to poverty alleviation, and broad-based agricultural development is a vital factor in achieving such growth. This means that local agricultural production is of central importance in economic development and poverty alleviation even ignoring national food security or self-sufficiency considerations. At the same time, such production cannot be driven solely by technology; equitable access to resources and services are critical to promote equity. This may involve some major challenges such as decentralizing government decision-making, reforming land tenure systems, and improving the provision of social services so that they serve the poor while remaining financially solvent. Decentralization and a greater voice for local people are important in this context. Finally, even equitable growth will not be sufficient to alleviate poverty and special measures are needed.

PART III. ISSUES FOR THE FUTURE

This part of the review examines a variety of issues that will be important in coming years to assure that agricultural research benefits the poor. These include the prospects for targeting research more directly to meet poor people's needs, the potential poverty alleviation implications of recent methodological and technological developments, and some issues related to evaluating the poverty alleviation impact of agricultural research.

While agricultural technology resulting from research may have pro- or anti-poor effects, evidence presented in Part II could be interpreted to mean that in most cases these outcomes are largely beyond the control of agricultural research. They depend on conditioning factors such as economic policies and institutions, the performance of service delivery systems, and the initial distribution of productive assets. Does this mean that agricultural research can proceed without consideration of its impact on poor people? Chapter 9 abandons this perspective and presents some approaches to target agricultural research explicitly to the needs of poor people; it also discusses the possible tradeoffs between productivity and poverty alleviation objectives.

Chapters 10 and 11 introduce recent developments in research methods and agricultural technology, and discuss their implications for poverty alleviation. Methodological developments refer to participatory research, which may be able to address poor people's needs simply by working with them on their priorities and giving them greater control over the research agenda and process. Technical developments discussed include biotechnology and precision agriculture, both of which have good prospects for raising agricultural productivity. Their likely poverty alleviation impacts, however, are uncertain and depend on the extent to which poor producers have access to them.

Chapter 12 discusses methods for assessing the impact of agricultural research on poverty alleviation. Understanding the use of these methods will become increasingly important as pressure grows for researchers to understand and demonstrate the impact of their research on poor people's welfare.

Before proceeding with Chapter 9, it is useful to set the stage by introducing three alternate visions of how to ensure that agricultural research contributes to poverty alleviation. These include 1) improving the execution of the existing research agenda with its focus on increased productivity, 2) shifting some research resources to a more explicit emphasis on poverty alleviation objectives, and 3) giving poor farmers and agricultural workers a greater say in the research agenda through participatory research. The first of these approaches is reviewed briefly here, while the others are discussed in more detail in Chapters 9 and 10, respectively.

Figures 4.1 and 4.2 presented alternate views of the impact of agricultural research on poverty alleviation. From the optimistic perspective of Figure 4.1, the priorities for future efforts to help poor people through agricultural research essentially call for improved execution of the existing agenda. For technology research, this means developing highly productive and widely adopted technologies, which in turn requires good coordination between IARCs and strong NARSs. Technology development for the poor will focus on greater tolerance to pests, diseases and drought and less dependence on inputs. There is implicit recognition that new solutions often create new challenges that the research system can address when the time comes. For social science research the optimistic framework means learning more about how socioeconomic conditions, policies and institutions determine technology adoption and better natural resource management, and then spelling out specific steps to translate understanding into action. Most of all, it will require improved governance in developing countries, particularly in reforming policies and institutions to facilitate agricultural growth that includes the poor. These steps are essential to ensure that the impact of agricultural research reflects the favorable situation described by Figure 4.1 and avoids the pitfalls represented in Figure 4.2.

Alternate views of the future role of agricultural research in raising productivity, alleviating poverty and protecting the natural resource base call for important changes in the way the system operates. Some of the more extreme criticisms are poorly documented and fail to present realistic alternatives. On the other hand, some highly legitimate criticisms offer suggestions for adjustments that could greatly help agricultural research achieve its mission and these are discussed in the next two chapters.

9. ISSUES IN TARGETING AGRICULTURAL RESEARCH TO BENEFIT THE POOR

According to the optimistic perspective of Figure 4.1, researchers should focus on generating the most productive technology while policy makers put systems in place to ensure equitable distribution of benefits. As long as policy makers do their job, agricultural research will help everyone. In short, for agricultural researchers poverty is "someone else's department."

The rationale behind this view is expressed forcefully by Alston et al. (1995). The main argument is that agricultural research is an effective tool for generating productive technology, but a blunt instrument for fighting poverty. Not only would orienting research explicitly towards poverty alleviation objectives be an inefficient means of fighting poverty, but also it would reduce the effectiveness of research in fulfilling its primary goal of raising agricultural productivity. In fact, from the perspective of Chapter 8, this would have negative implications for poverty alleviation by reducing economic growth potential. Alston et al. argue that for these reasons, it is much better to let agricultural research focus exclusively on increasing productivity and employ other means to fight poverty. These would include the kinds of approaches discussed in Part II: redistributing land resources, promoting labor-intensive economic growth through improved infrastructure and services, building poor people's human capital through investments in education, health and nutrition, and implementing targeted safety net programs to transfer income to poor people.

A second school of thought argues that this "business as usual" approach to agricultural research is evasive and irresponsible. The main point of this argument is that even if improved policies and institutions were the best way to reduce poverty in principle, in practice such change is always slow and usually incomplete. In short, if we wait for better policies and institutions to solve the poverty problem, we will be waiting for a long time and possibly forever. Meanwhile, many anti-poverty programs in developing countries have high costs but questionable effectiveness, so alternate approaches are needed (Ruel and Bouis 1997). Also, Reutlinger (1996) makes the point that any given poverty reduction approach has diminishing returns, so employing multiple approaches represents sound economics. Accordingly, if agricultural research offers opportunities to alleviate poverty then they should be tested. Besides, if the economic returns to agricultural research were as high as cited in Chapter 3, surely it would be acceptable to trade off a portion of those efficiency gains for a greater poverty impact.

Which of these two perspectives is correct? The answer is that the evidence is insufficient to draw conclusions. Analysis of this question is needed. Meanwhile, innovative approaches to skew to focus of agricultural research to poverty alleviation objectives should be considered for testing.

POSSIBLE APPROACHES TO TARGET AGRICULTURAL RESEARCH TO THE POOR

There are many ways to target research to benefit poor people. Crop breeding can target crop characteristics considered to be important to poor people, as in the case of high-lysine cereals discussed in Chapter 7. Research can target crops consumed predominantly by poor people within a region, or it can target regions or ecosystems with a large population of poor people. The approach to research may have implications for its impact on the poor. Participatory research, for example, may hold the potential for both improving researchers' understanding of poor people's priorities and enabling poor people to help develop solutions to them. Chapter 10 will discuss participatory research in some detail. The type of research may also be relevant to targeting the poor. Is plant breeding, or natural resource management, or some other area of agricultural research more relevant to poor people's needs than others?

Plant Breeding for Nutrition Objectives

As was discussed in Chapter 7, researchers at ICRISAT rejected the idea of breeding for high protein and lysine content in food grains because it turned out that low calorie consumption was a more severe problem than low protein or lysine consumption. As a result, breeding for high yield was the best way to help poor people and there was no tradeoff between efficiency and equity objectives.

In recent years, however, an analogous problem arose with respect to human consumption of micronutrients such as iron and zinc, which are critically important to human nutrition. Micronutrient deficiency is an important source of malnutrition. Typically governments try to overcome nutrient deficiencies by fortifying foods (adding nutrients during processing) or supplementing their diets with foods rich in the nutrient in question, or encouraging them to diversify their diets on their own. Ruel and Bouis (1997) discuss the prospects for raising human zinc intake through a completely different mechanism: breeding plants that absorb more zinc from the soil and make it available to people who eat them. Several questions remain about the biological feasibility of this approach, both concerning the plant's ability to absorb zinc from the soil and humans' ability to absorb it from the plant. For plant breeding, breeding for zinc uptake will entail costs by drawing resources away from other objectives, such as raising yield potential or strengthening tolerance to various stresses. Whether or not these costs are worth bearing is an important question for addressing poverty alleviation.

Evaluating such tradeoffs can have high stakes, considering that Bohn and Byerlee (1993) estimated that breeding a new wheat variety costs about US $1 million, or about $2 million when considering only successful varieties. Also, the cost rises at least proportionally with the number of traits emphasized (Francis 1991; Arnold and Innes 1984, cited by Byerlee 1996). In other words, breeding for both zinc uptake and pest resistance would raise the expected cost of developing a successful variety from $2 million to $4 million. Ruel and Bouis (1997) describe a 10-year micronutrient breeding program that will cost about $20 million. At such high costs, it is easy to appreciate Alston et al.'s call for addressing poverty concerns through other means.

However, when Ruel and Bouis compared the cost of the breeding program to other approaches, they found that $20 million did not seem so expensive. A food supplementation program well targeted to reach half of India's anemic pregnant women, for example, would cost $2.65 per person or a total of $37 million each year. A fortification program that reached half the population would cost almost $50 million every year ($0.10 per person). Other kinds of poverty alleviation programs are also expensive. India's annual budget for watershed-based poverty alleviation programs, for example, is about half a billion dollars (Turton et al. 1998). From this perspective, targeting crop breeding for increased human consumption of micronutrients could make economic sense. The primary issue may be technical feasibility rather than cost (Ruel and Bouis 1997).

These questions about the costs and benefits of alternate research priorities are complicated and characterized by a shortage of evidence. The figures presented by Ruel and Bouis most probably justify testing of alternate breeding objectives in order to gain more experience and information about the possibilities. On the other hand, they do not justify large-scale shifts of focus. It is important to keep in mind that in countries with scarce resources for plant breeding, even a small experiment on plant breeding for better human nutrient uptake would certainly displace some other experiment with a different focus. Unproven ideas should be tested in settings with sufficient capacity that there would be less displacement of more proven research approaches.

Targeting Commodities that Poor People Consume

Walker and Ryan discussed targeting research to commodities that will have the greatest impact on poor peoples' energy intake. They identified commodity priorities by measuring their nutrient content and their share in poor people's diets, calculating each crop's price elasticity of demand, and then calculating the likely change in poor people's consumption of each crop if prices fell due to higher output resulting from improved technology. Through this approach it is easy to determine which food crops to target in order to have the greatest impact on poor people.

Developing Technology to Benefit Laborers

Just as crop breeding can target human nutrition priorities, agricultural research may be able to target labor demand. Pretty (1995) suggested that there may exist unexploited opportunities to develop green manure-based soil nutrient management systems that would employ more workers. Farmers would trade expenditure on chemical fertilizer for expenditure on laborers, and poor laborers would benefit. Of course the feasibility of such an approach depends critically on the relative costs of labor and fertilizer, along with the technical feasibility of green manure. But if these factors appear to be favorable, then such an approach to research could be very beneficial in very poor countries.

In the longer term, one inherent problem of labor-intensive agricultural development strategies is that they become less feasible economically as wages rise. Of course rising wages are a central feature of poverty alleviation, so it should not be surprising that, throughout the world, agriculture becomes increasingly capital intensive as per capita incomes rise. This may imply that developing more labor intensive agricultural technology is attractive for the poorest countries but only as long as wages remain very low.

Walker and Ryan (1990) discussed the implications of the seasonality of agricultural production. Some researchers have suggested the need for technologies and practices to make the demand for labor and other inputs more stable over the course of the cropping season or the year. For India, Walker and Ryan suggested that seasonal wage peaks are important to the poor because they offer laborers substantial income earning opportunities. Ironing out the labor demand peaks could actually hurt the interests of the poor by eliminating high wage periods, even if overall labor demand rose. Of course, it would also reduce the incentives for further mechanization.

Targeting Areas Where Many Poor People Live

Targeting agricultural research to areas densely populated by poor people is another way to bring benefits to a large number of people. The Rockefeller Foundation's ten-year program to promote rice biotechnology in Asia is a good example of this approach. ICRISAT's mandate to work in the world's semi-arid tropical areas is another.

Socioeconomic Research to Assess Tradeoffs and Set Priorities

One obvious prerequisite for targeting agricultural research to help poor people is to develop a better understanding of the opportunities to do so. An excellent example is ICRISAT's findings from socioeconomic research that poor people would benefit more from varieties that raised output and reduced prices than varieties with higher protein or lysine content. This research, described in Chapter 7, provided clear information regarding the likely nutritional impacts of alternate breeding approaches. Research managers armed with this information could easily assess the tradeoffs involved in allocating resources between one approach and another.

Impact assessment and priority setting in agricultural research have received a great deal of attention in the last decade due to budget pressure. Most of the work has focused on efficiency objectives, however, and poverty alleviation is usually addressed only indirectly. It is difficult to find analyses of tradeoffs involved in shifting some research resources to address poverty objectives. Clearly such information is needed and this is discussed further in Chapter 12.

IMPLICATIONS FOR RESEARCH POLICY

When considering targeting agricultural research to poverty alleviation objectives, several important issues arise regarding organizing research and setting the research agenda. For example, what should be the respective roles of the private and public sectors? How will new intellectual property rights regimes affect the opportunities for poor people to benefit from agricultural research? This section raises some such issues but does not attempt to provide definitive answers. The problems are complex and some of them are evolving quickly, and this review has stopped short of covering the relevant literature in detail.

Also, discussion of two important research policy questions is postponed until subsequent chapters. Chapter 10 discusses the issue of promoting more participatory research, while Chapter 11 discusses ways to harness biotechnology to solve problems facing poor people in developing countries.

ROLE OF PUBLIC AND PRIVATE SECTORS

As introduced in Chapter 3, the private sector has a greater incentive to conduct research whose returns are relatively quick and whose benefits can be captured privately. This means that private firms have comparative advantage in applied or adaptive research on products such as hybrid seeds, machines, and chemical inputs. Without special incentives or secure, long-term funding and patent protection, the private sector will be less poised to conduct research on basic or strategic research with applications to agriculture, or on products and practices that cannot easily be sold for private gain. The latter include open-pollinated seeds, management practices that are not tied to the use of particular inputs, and technologies or practices that offer environmental gains not captured solely by their user. In the 1990s, changes in intellectual property rights regimes offer the private sector the opportunity to reap private rewards even from open-pollinated seeds, at least in principle. Where it is enforced, the opportunity to patent open-pollinated seeds will give the private sector greater incentive to conduct scientific research to develop more productive technology.

Meanwhile, the agricultural sector in all countries is becoming increasingly commercialized. This expands the private sector's role, not only in producing agricultural technology but also in marketing inputs and outputs. Commercialization contributes to higher agricultural productivity and economic growth, which can help poor farmers and laborers as long as the distribution of assets, policies, institutions and infrastructure are all-favorable. The private sector already funds about 50 percent of agricultural R&D expenditures in OECD countries (Alston et al. 1998b), and it is small but growing in the developing world. All this suggests that not only is the private sector firmly entrenched in commercial agriculture, but its role is likely to continue to grow in the future.

A greater private sector role in developing country agricultural research could lead to additional technical breakthroughs and relieve pressure on scarce public funds. However, private sector research would likely focus on commercial farming in favorable areas and bypass marginal areas with small markets (Byerlee 1996; Messer and Heywood

1990). Also, the private sector would only have an incentive to get involved in plant breeding if it works on hybrids or if there is strong enforcement of intellectual property rights for open-pollinated varieties that it develops. Byerlee (1996) notes that the private sector is heavily involved in plant breeding in Latin America, where hybrid maize is widespread. It also does a lot of work in sorghum and millet in India, and it is getting involved in hybrid rice in Asia. However, to date the private sector has not shown a comparative advantage in developing a market for hybrid seed in noncommercial, small farm agriculture. Successful cases have combined public sector research and extension with private sector seed production and marketing. Similarly, even with enforcement of intellectual property rights (IPRs), the private sector would not have much incentive to introduce open-pollinated varieties in small farmer areas because the cost of enforcing IPRs would probably exceed associated revenues. As a result, wheat and rice will remain the domain of the public sector in most developing countries until hybrids are established for those crops.

Byerlee suggests that while the private sector will not replace the public sector anytime soon, there may be complementarities between public and private sector activities. The public sector can focus more on basic and strategic research, on crops dominated by open-pollinated varieties, and on the problems in marginal areas. A more extreme expression of this idea is that the private sector can be counted on to support commercial agriculture, leaving the IARCs and NARSs to target their resources almost exclusively to poverty alleviation and environmental protection.

A FINAL WORD

Even for those who support targeting agricultural research to address poor people’s needs, it is critically important to keep in mind that such targeting would not substitute for other prerequisites discussed in Chapters 5-8. Policies and institutions that support equitable access to technology and broad-based economic growth will remain probably the most important factor in ensuring that agricultural research helps alleviate poverty.

10. PARTICIPATION AND EMPOWERMENT IN AGRICULTURAL RESEARCH

While Chapter 9 suggested possible ways to target traditional agricultural research efforts towards solving problems deemed particularly important to poor people, this chapter introduces the idea of making agricultural research more collaborative between researchers and the poor people who are their clients, so that the poor can play a direct role in defining research problems and designing solutions to them.

Participatory agricultural research involves varying degrees of collaboration between researchers and farmers in diagnosing the systems in which they make decisions, identifying opportunities for bringing about technical changes, developing technologies and disseminating them. It has the potential to make research more effective by better identifying the most pressing problems, ensuring that proposed solutions are grounded in a thorough understanding of farm-level constraints, and enhancing farmers' problem-solving skills. Participatory research also has the potential to empower farmers by giving them a role in setting and executing the research agenda and by building their own human capital. To the extent that poor people participate in such an approach to research, it has the potential to be more effective in addressing their needs.

Farmer participation in agricultural research was initiated as a result of the relatively poor performance of traditional research approaches in developing useful technologies for resource poor farmers and less favorable conditions (Farrington 1989). In the traditional transfer of technology approach, technologies are developed on experiment stations and transferred to farmers through extension systems. Usually the technologies are developed on the basis of researchers' preconceptions about how farmers make decisions and the kinds of technologies they want. This system has worked extremely well for commercial agriculture in favorable areas where farming systems and agroecological conditions resemble those on research stations.

Technology development for agriculture under less favorable conditions, however, has proven more challenging. Farmer enterprises are more complex, with multiple sources of livelihood and complex linkages among them. Economic models built to predict how and why farmers adopt technologies are often inadequate under these conditions (Farrington 1989). Subtle interactions among components of household livelihood systems make it difficult to predict what changes may be acceptable to farmers or the criteria by which they may evaluate new technologies. Conditions are spatially diverse; sometimes technologies need to be tailored to suit different conditions.

Farmers gain control over the research agenda to the extent that they influence research priorities. The extent of their influence depends on the nature of their participation. Also, whether it is adequate to make research more responsive to the needs of the poor depends on whether the poor are represented among those participating. Participatory research by itself does not give farmers the power to influence the research agenda; under existing institutional arrangements researchers and the research system must facilitate such empowerment.

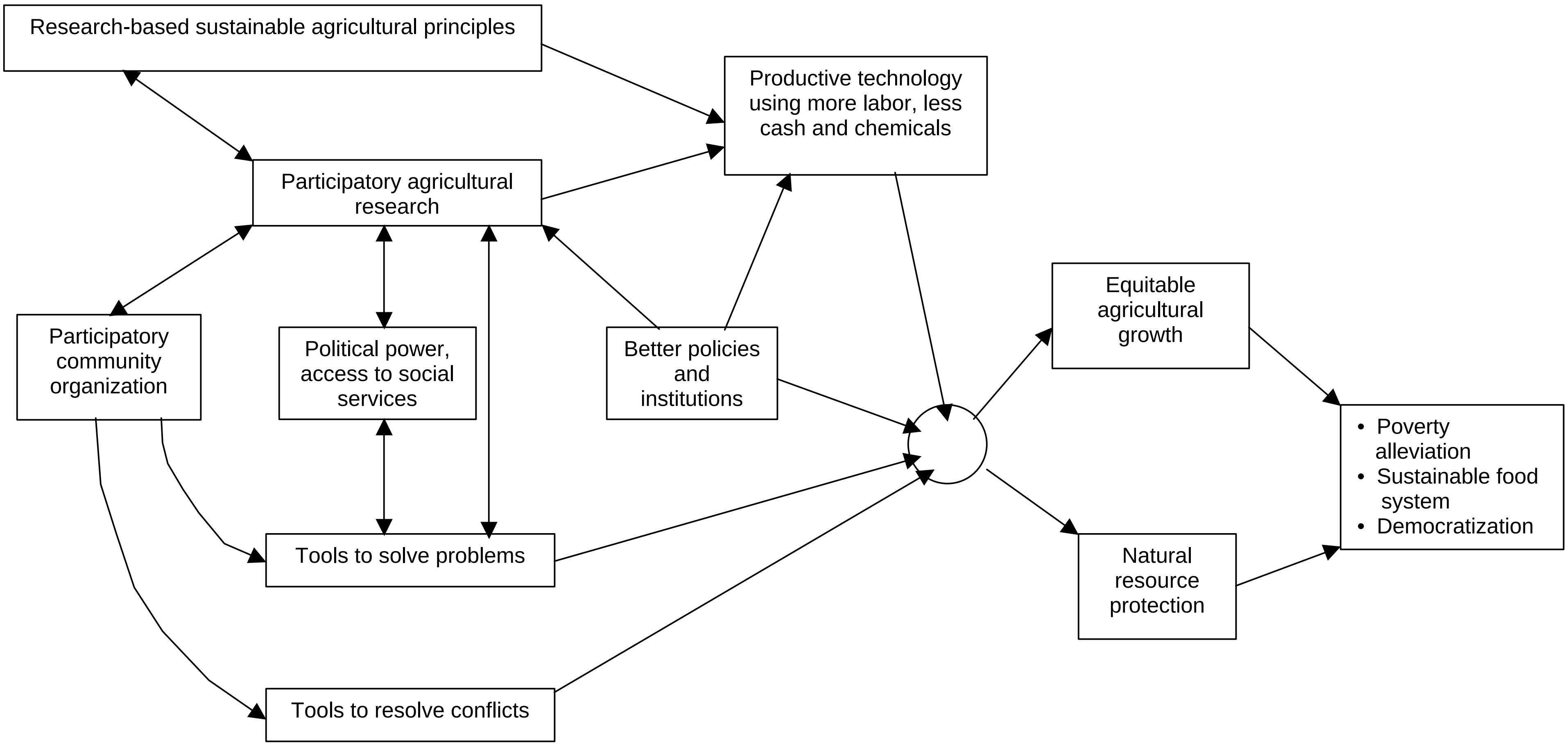
Participatory research also aims to take advantage of farmers' knowledge and capability to experiment. The idea that farmers actively use their knowledge to evaluate different techniques has become an argument for involving them in research. The aim of participatory agricultural research is to jointly identify problems and opportunities, identify a number of options based on indigenous knowledge and formal science, and then experiment locally (Chambers et al. 1989; Okali et al. 1994). Participatory research therefore requires a collegial relationship between researchers and farmers so that they can learn from each other and truly collaborate in developing technologies. The emphasis on building farmers' innovation skills and giving them a central role in the research process gives participatory research a broader objective of empowerment (Okali et al. 1994; Scoones and Thompson 1994). The focus on empowerment, that is to build farmers' capacity and influence, distinguishes participatory research from other research that may be only client-responsive.

PARTICIPATORY AGRICULTURAL RESEARCH AND COMMUNITY DEVELOPMENT

Participatory research must take place in the broader context of community organization and development if it is to address the problems of all groups of rural people, including not only relatively influential farmers but their weaker neighbors with small holdings or no holdings at all. Without a solid understanding of communities with which they work, it will be difficult for researchers to identify less influential groups and ensure that they participate effectively in research. This suggests two things: first, participatory research will be both easier to organize and more effective in reaching poor people if communities are already organized and have the necessary skills to work together, solve problems as a group, and resolve conflicts when they arise. Second, communities that have these skills can apply them not only to agricultural research but a broad range of other development priorities. This includes provision of the kinds of services that this paper has argued are critical to ensure the equitable distribution of benefits from agricultural technologies. For example, a small but growing number of cases from around the world show that through participatory community organization, usually with facilitation from a committed local leader or a high quality NGO, villagers can jointly identify priorities and take steps to act upon them. They establish and manage credit funds, identify and gain access to better technologies and marketing channels, protect their natural resources, and exert influence on political leaders (Pretty 1995; Chambers 1997; Nelson and Wright 1995; Uphoff et al. 1998).

Combining progress in participatory community organization and participatory research would ideally lead to a path of agricultural development along the lines of Figure 10.1. In this framework rural people (and their representatives, including NGOs, local councils or religious organizations) play a greater role in both agricultural research and provision of services such as credit, and scientists search for techniques that require fewer cash- and chemical-intensive inputs. Often this approach is portrayed as an incompatible alternative to the existing commercial agricultural system, but there may be great scope for incorporating elements of both.

Figure 10.1: Participatory community organization and agricultural research to alleviate poverty and raise productivity.



Under this framework, poor people would play a central role in identifying socioeconomic and technical problems, setting research and development priorities, conducting agricultural research, and building social institutions for such services as credit and extension. Participation would improve service delivery for everyone while empowering the poor and other marginalized people by giving them a voice in the development process where normally they have none. Part of the rationale here is the criticism of the optimistic agenda's simplistic call for better governance despite evidence that such positive change is very difficult to implement. The approach would be linked to participatory community organization efforts as described above. This would be essential to providing an organizational basis for participatory research.

Under the framework of Figure 10.1, a focus on participation would incorporate a stronger commitment to the development and diffusion of more environmentally benign practices. "Sustainable agriculture" is a loose term that describes approaches to increase agricultural productivity by managing natural environmental processes with reduced use of chemical inputs.[10] Perceived complementarity between participatory research and a dedication to the principles of sustainable agriculture is based on the assumption that poor farmers would favor approaches that require less cash, and that scientists would come to appreciate traditional farming systems that rely less on external inputs. It is important to note that, as evidence in Chapter 3 hints, the views of mainstream agriculture and relatively moderate sustainable agriculture are probably closer to each other than sometimes might be expected.

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[10] Under such systems, soil fertility is maintained through the use of organic amendments along with cropping patterns and crop rotations that supply green manure to crops, human laborers are favored over herbicides, and pests are controlled through natural predation and the use of diverse cropping patterns to minimize losses. In its extreme form the sustainable agriculture school of thought opposes the use of any external inputs. A more moderate viewpoint, however, calls for reducing reliance on them and searching for alternate approaches that balance the use of organic and inorganic inputs (Pretty 1995).

The issues involved in participatory community development are vast and cannot be addressed here. The important point for the purposes of this paper is that it is highly complementary not only to conducting participatory research but also to making the most of the products of research, whether participatory or otherwise.

WHAT IS PARTICIPATORY RESEARCH AND HOW IS IT DONE?

Participatory agricultural research includes a wide range of research processes that involve farmers to various degrees. Farmers can participate in any stage of research: diagnosis and identification of constraints and opportunities, technology development, or field-testing. The degree of their participation can be characterized as ranging from contractual at one end to collegial at the other, with consultative and collaborative research in between (Biggs 1989). In the contractual, or least participatory mode, farmers may take part in the inquiries and experiments of researchers, who set the agenda and make all decisions. In the consultative mode, researchers may only consult people before taking action; they have conducted all the prioritization and organizational work beforehand. In the collaborative mode, researchers and farmers may work together on projects controlled by the researchers. Farmers may have the opportunity to provide input into the research process, but the researcher has the final say. In the collegial mode, farmers and researchers work together and learn from each other as equals, with local people having control over the research process. Research in this mode is intended to make full use of the capabilities of both researchers and farmers.

Another way to characterize the range of farmer participation is on the basis of farmer-researcher relationships and sharing of decision-making powers. At the least participatory end of the scale, the relationship between farmers and researchers is unequal: farmers' knowledge is not considered valuable, only formal science is considered to be useful in developing technologies, and scientists' role is to provide solutions for farmers. Scientists may seek information from farmers, but in an extractive manner: for their use, to be interpreted within their own framework. The scientists define the problems and make all the decisions. At the other extreme, the relationship is much more collegial: scientists value farmers' knowledge and recognize their capability to find solutions. Their role is to help farmers find solutions to problems by building their capacity for experimentation and innovation. Farmers' concerns and priorities dominate all stages of technology development.

What level of participation is best? This depends on the objective and the problem at hand. If the objective is to empower farmers by building their capacity and giving them more influence over the research system, then more participation is better. If the objective is simply to improve research performance, then participation is likely to be more useful for solving some kinds of problems more than others. Identifying constraints and opportunities in farmers' fields, identifying attractive technologies and understanding what makes them attractive, and developing new management practices suited to farmers' fields are all cases where farmer participation has an obvious role to play in developing technology.

Several examples help illustrate the broad spectrum of farmers' participation in agricultural research. It is useful to begin with farming systems research, which represented a first step toward farmer participatory research and is perhaps its direct precursor. Developed in the 1970s, farming systems research emerged as a response to the need to understand the complex systems under which farmers made decisions, and to identify opportunities for technical change within these systems (Farrington and Martin 1988; Cornwall et al. 1994). Farming systems research seeks to determine research objectives by explicitly identifying farmers' needs and develop agricultural technology within the context of whole farm systems (see Box 10.1). This distinguishes it from the traditional approach to research in which interventions are based on individual commodities or factors. Farming systems research also includes field-testing of technologies; its impact may have been most significant in understanding the systems and identifying farmers' technology requirements. It may have been less effective in responding to the needs identified, largely because the top-down management of research organizations was ill-suited to respond to needs identified by field researchers (Byrnes 1990). Despite its limitations in involving farmers in technology development, farming systems research was an important first step towards participatory research. It also has been adopted widely by social scientists.

Box 10.1. Farming Systems Research on Crop-Livestock Interactions in Swat Valley

Farmers in the Swat Valley, Pakistan, intensively cultivate small plots in holdings that average a little more than one hectare. Livestock is a major component of their system and maize is the major crop. These farmers had failed to adopt some of the recommendations of the maize package of practices such as line planting, use of low seed rates, early thinning, and use of pesticides. Even a major research and extension program in the 1970s failed to persuade farmers to adopt anything more than improved varieties and fertilizers. Researchers felt that lack of adoption of low seed rate and early thinning was reducing maize yields. They knew that fodder production was important to farmers in Swat Valley, but the conventional view was that it is better to produce maize grain and maize fodder in separate fields.

A major effort was initiated in 1983 by a multidisciplinary team of agronomists and social scientists to understand why farmers were rejecting some of the recommendations. Diagnostic surveys were conducted to understand the system better, and on-farm experiments were conducted to test the available technology under farmers' management. The study revealed that livestock were important particularly to small farmers; their livestock holdings were expanding and they were shifting towards stall-feeding buffaloes. Farmers who maintained higher than recommended population were aware that it reduced maize grain yields, but they followed this practice so that they could use the plants removed during thinning as fodder for their livestock. During the course of the season they would remove nearly 100,000 plants per hectare for use as fodder. The value of the green and dry fodder they harvested was equal to that of grain. Even though maintaining the recommended population could increase grain yield by more than 40 percent, increased costs and the loss of green fodder would make it less profitable than their existing practice.

Farming systems research enabled researchers to understand this complex system in a way that conventional methods of inquiry would not have. They pointed to the need for breeders to screen varieties for tolerance to higher planting densities. Incorporating traits such high yield at increased densities, leafiness and storability and palatability of stover would make the varieties more acceptable to farmers.

Source: Byerlee and Khan (1992)

Farming systems research was associated with the development of rapid rural appraisal, or RRA, which represented a more holistic yet cost-effective means of obtaining information than traditional questionnaire surveys. Questionnaires are constrained by the preconceptions of their designers and, unless they are narrowly focused on a problem about which the researcher already has a good understanding, have great scope for completely failing to obtain important information simply because they may not contain all the relevant questions. RRA is organized around a set of open-ended research questions, and the researcher begins with an open mind with regard to where the discussion will go. It is useful for identifying constraints and developing research questions and hypotheses.

Participatory rural appraisal, or PRA, evolved from RRA in part because of an interest in giving a greater voice to the research subjects, but more importantly as a means to empower them to identify, analyze and solve their own problems. It is based on a set of tools that help local people express themselves, but in fact it represents an entire approach to empowering local people to identify, analyze and solve their own problems. Table 10.1 shows the major differences between RRA and PRA, and it helps demonstrate the thinking the led to the evolution of participatory research from farming systems research.

Table 10.1 Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA) Compared.

Item	RRA	PRA
Period of development	late 1970s, 1980s	late 1980s, 1990s
Major innovators	universities	NGOs
Main users	aid agencies, universities	NGOs, government field organizations
Key resource earlier overlooked	local people's knowledge	local people's capabilities
Main innovation	methods	behavior
Outsiders' mode	eliciting	facilitating
Objectives	data collection	empowerment
Main actors	outsiders	local people
Longer-term outcomes	plans, projects, publications	sustainable local action and institutions

Source: Chambers 1997

Participation is becoming more common in the final stages of research where technologies developed on-station are field tested or adapted to different conditions. Participatory evaluations of crop varieties are good examples (Weltzien et al. 1998; Joshi and Witcombe 1988; Thakur 1998; Joshi et al. 1997). On the basis of initial surveys or PRA exercises to identify the range of varietal attributes that farmers find desirable, a number of varieties or advanced lines with the desired traits are selected for on-farm trials. Management of the trials is left to farmers in some cases, while in others they are controlled by the researchers. Some trials are set up as experiments with replications, and in others farmers raise the crop as they would raise their local varieties. Researchers who want statistically valid data organize the trials to resemble experiments as closely as possible. Farmers evaluate the performance of varieties based on criteria of their choice. In some cases, researchers make specific efforts to ensure that women and poorer farmers participate in on-farm evaluations. Group processes are also employed to various degrees in gathering farmer perception. The exercises usually provide useful information on the varietal attributes that farmers prefer under different conditions.

Farmers may also participate in earlier, product development stages of research. In a bean-breeding program in Rwanda under the International Center for Tropical Agriculture (CIAT) (Sperling et al. 1993), farmers were involved in on-station trials of beans before lines were identified for on-farm testing. Because farmers were involved early in the on-station phase of the research, they were able to identify varieties with both promising agronomic and socioeconomic features. Researchers would not have anticipated the importance of some of the attributes without farmers' input, so this approach saved several seasons of on-farm testing. Farmers were able to predict on-farm performance of different varieties on the basis of their performance on-station, leading to superior matching of available lines to specific locations. This involved the identification and release of a much larger number of varieties than in previous years, each one suited to relatively specific conditions. The usual research approach had been to identify a very small number of varieties with broad suitability to a wide range of conditions, but the new approach delivered much higher on-farm yields.

A second phase of this program gave Rwandan farmers an earlier role in the on-station selection process with greater responsibility, and it gave communities greater responsibility to select their own representatives and organize their own procedures for on-farm testing. An important lesson of this phase was institutional: community politics influenced the selection of farmers for the program, and many of them proved not to be very capable (Sperling and Scheidegger 1995). This experience highlights the concern raised earlier that institutionalizing participatory research will require developing ways to work more effectively with community groups, including the poor and less influential. Work on this topic is gaining progress (Ashby and Sperling 1995; Ashby et al. 1995).

Similar approaches were adopted in a project to identify appropriate soil conservation technologies for cassava-based farming systems in Southeast Asia (Howeler 1997), and for field testing of improved fallow technology in Zambia (See Box 10.2). In the soil conservation project in Southeast Asia, PRA exercises were conducted at the sites to understand local farming practices and farmers' perceptions of soil erosion problems. Scientists selected technologies for demonstration and asked farmers to evaluate them. They also asked farmers to describe their own practices. On the basis of farmer evaluations, a few technologies were selected for on-farm testing. Many of the farmers who volunteered to test the technologies adapted them to suit their own conditions. Farmers managed the trials under guidance from project staff who collected data on the performance of various technologies. The results indicated that the practices farmers considered most useful varied among different pilot sites. Farmers preferred technologies that improved cassava yields in addition to conserving soil. In the case of field testing of improved fallows technology in Zambia, technology adoption became widespread even while it was being tested. The extension system that helped in organizing field-testing became a partner in the research, providing valuable feedback to researchers.

Box 10.2. Improved Fallows in Eastern Zambia

Declining land productivity is a critical problem in Zambia as in much of tropical Africa. Fallowing, a practice adopted by farmers to build up soil fertility, has reduced due to increasing land scarcity. Fertilizer use has also declined dramatically with the withdrawal of subsidies. In 1987, following surveys indicating that declining soil fertility was a major concern of farmers, the Zambia/ICRAF agroforestry research project began trials on improved fallows in which leguminous trees were grown in fallow lands to build up soil fertility. On-station trials showed that a two-year improved fallow using this practice, which was indigenous to some of the regions under study, was likely to be profitable for small farmers.

On-farm trials began in 1992/93 with 5 five farmers and the number grew to 204 in 92/93 and nearly 3,000 in 1996/97. Farmers chose from one of six technologies for trial. They raised trees for two years followed by maize in the third, fourth and the fifth year; they also raised maize continuously for five years in control plots.
The project established a network as it supplied planting material, training and information to extension organizations, development projects, NGOs and farmer groups. Monitoring surveys were conducted by a researcher, a technician and an extension staff member in some cases. A semi-structured survey was conducted after the first post-fallow maize crop to assess farmers' experiences. Several surveys were conducted to get information on the association between management practices and sapling survival rates, and farmers' management responses. Several meetings of the network have been held in which researchers obtained useful feedback.

Preliminary results indicate that improved fallows are more profitable than unfertilized maize production without fallowing. They were not more profitable than fertilized maize without fallowing; the returns to labor were marginally higher, but returns to land were lower.
The technology is spreading without specific efforts. The number of farmers testing the technology is growing, and they are providing useful feedback to researchers on its performance. Adaptive research has been combined effectively with the extension service, which has become a partner in the research.

Source: Franzel et al. (1999)

Box 10.3: Integrated Pest Management with Kenyan Farmers

An integrated pest management project was initiated out of concern about increasing use of pesticides on coffee and vegetables in the Kenyan highlands. The Farmer Field School (FFS), which aims to put people through discovery-based learning, was adopted to introduce integrated pest management practices. The objective of the FFS is to increase the capability of farmers to develop their own solutions to problems. Farmers in groups of 10 to 20 were trained over a 6 month period in 1996 in 4 districts by trainers from the Ministry of Agriculture and research institutes. The IPM principles imparted to the trainees related to natural biological control and the link between crop nutrition and tolerance to pest and diseases. The curricula were developed to meet local needs and concerns identified through PRA exercises. The trainees were exposed to a number of management practices that could solve problems on their fields. The solutions to their problems were known, but training was imparted in such a way that trainees had to rediscover them. An essential aspect of training was also to encourage them to experiment.

An evaluation conducted in late 1997 in which trainees' practices were compared with those of a control group showed that the trainees had made more planned changes in their management practices compared to others. They had changed management practices of crops not covered in training, suggesting that they were applying the principles they had learned to solve a wide range of problems. The changes they had made in crop management practices related to botanical, physical and cultural control of pests and careful application of manure and compost. The graduates had shifted towards non-chemical pest and disease control measures. The graduates diffused both what they had learned and their own innovations among their neighbors. Diffusion of knowledge took place along gender lines; male trainees served as sources of information for other men, and female trainees for women. The benefits from the program to trainees in terms of cost savings were substantial. For example, the trainees were spending $145 per household per year less on agrochemicals.

Source: Loevinsohn and Meijerink (1998)

Two projects to develop integrated pest management (IPM) practices, in Kenya and Honduras, focused on improving farmers' capacity to innovate. The farmers were trained and then left to experiment on their own. The project in Kenya employed the Farmer Field School (FFS) method in which farmers undertake group-based learning and then are encouraged to experiment beyond the specific methods they have learned (Box 10.3). In Honduras, farmers' training focused on filling in some gaps in their knowledge to stimulate them to innovate (Box 10.4). In both Honduras and Kenya, farmers adapted what they had learned to their situations and developed their own experiments to develop new technologies.

Box 10.4: Integrated Pest Management with Honduran Campesinos

Extended interactions with farmers in Honduras revealed that while they may have excellent knowledge of some things, there are a lot of things that they do not understand adequately. For example, they thought that all insects were bad. They did not know about parasitism, by wasps and flies on common crop pests. They also had limited understanding of insect reproduction. Filling these gaps in their knowledge could help them innovate to control the pest naturally.

Over a two-year period, 650 farmers, para-technicians and extension agents of farmer origin who were working for NGOs were trained in natural pest control in 3-day training programs. The motto of training was to "find out what people know and explain what they don't know in a way that is compatible with what they do know." They were taught about insect reproduction, predators, insect diseases, and ways to manipulate crop pests' natural enemies. Emphasis was on field experience. Learning took place through field activities such as collecting insects and classifying them according to their ecological role, digging holes to see the effect of plowing on insect population, observing insect behavior for extended periods to see how they feed on crops and on each other, splitting maize stalks to see the larvae of stem borer and the pupae of its parasites. These tasks were repeated to ensure learning, in a manner that did not make it boring for the trainees. In addition to imparting basic knowledge on biology and ecology, farmers were also familiarized with some pest control techniques that they were not aware of. An examination at the end of training revealed that they had absorbed as much as 80 percent of the knowledge imparted to them.

The researchers visited 52 ex-participants from all over Honduras the following year. 23 of them had adopted at least one of the technologies they had learned. An equal number had experimented and invented technologies of their own, making use of what they had learned in training and what they already knew. New ecological ideas presented to them had stimulated them to innovate. Some of the experiments they conducted included transporting the nests of natural enemies such as wasps and ants to their fields, using light traps to capture adult insects whose larvae would later damage their crops, attracting ants, and using children to remove pests by teaching them about which ones were good and which ones were bad.
Some of the good experimenters were invited to the research station to present their work to scientists, and to each other, to stimulate them by recognizing their work and also to spread the technologies.

Source: Bentley et al. (1994)

The Kenya and Honduras cases had a very high degree of participation in technology development. In both cases, researchers' role was mainly facilitation while farmers' capability was enhanced. In a sense the researchers were really trainers who imparted problem-solving skills. In the case of Honduras, training focused not on familiarizing farmers with pre-selected technologies, but on teaching principles that enhanced their understanding of their ecosystem and enabled them to be innovative.

It is important to note the differences in the types of technologies developed in all these cases. The extent of effort required involving farmers and the respective roles of formal science and indigenous knowledge in developing the technology depends on the kind of problem. In the Kenya and Honduras cases where the objective was to develop location-specific natural pest control measures, there were definite advantages to letting farmers take the lead in technology development.

POVERTY IMPLICATIONS OF PARTICIPATORY RESEARCH

As participatory agricultural research is still an emerging field, the literature on the contributions of participation remains limited. Analysis of participatory research's impact on agricultural productivity is scarce while that on poverty alleviation is practically nonexistent. Nevertheless, early studies such as those described in this chapter suggest that participatory research has strong potential to contribute to productivity and poverty alleviation objectives. The major implications for poverty alleviation are as follows:

- Participation can help bring improved technologies to diverse, low productivity areas that traditionally have been poorly served by the agricultural research system. Higher productivity in these areas will contribute to poverty alleviation through the mechanisms outlined in Chapters 5-8.
- Through collaborative research approaches that strengthen farmers' innovation skills, participation can build poor farmers' capacity to solve their own problems without waiting for assistance from outside.

- Participation that increases farmers' influence over the research agenda will empower them to demand a focus on problems of greatest importance to them.
- Participation can also bring a focus on the specific needs of poor farmers, but only with a concerted effort to ensure that the poor are among those who participate. Traditionally agricultural researchers have communicated primarily with the wealthiest, best educated and most mobile farmers, while the poorest producers and workers have had little opportunity to express their concerns. Even in explicitly participatory approaches it is easy for dominant members of a community to monopolize communication processes. But if researchers recognize this problem and make the effort to understand a community's social, political and economic structures, they can devise approaches to work with the poorest people and address their needs. Doing so will require collaboration between agricultural researchers and others who have a better understanding of the community.

PROSPECTS FOR THE SPREAD OF PARTICIPATORY RESEARCH

Participatory research is a growing field. It is still carried out mostly in small circles within international research stations, NGOs and a few NARSs. Adoption of participatory approaches in international centers can be expected to have spin-off effects on other organizations such as NARSs and private organizations working with international centers (Rocheleau 1994).

To reiterate from above, the objectives of participatory research can include either improving the effectiveness of research or empowering farmers, or both. Participation to promote empowerment has grown only recently in agricultural research. Within a small base, there is much experimentation going on and rapid expansion of knowledge about how to approach empowerment, what forms it can take and how much empowerment can be achieved. Progress in this regard is linked to progress in participatory community development, since institutionalizing participatory research that is empowering for all, including the poorest community members, requires working with communities that are organized and skilled in working together, solving problems and resolving conflicts. Participatory research in turn can contribute to further strengthening the skills of such communities.

Though hard-core proponents of participatory research may not accept anything less than empowerment, even farmer participation that is only consultative can improve research effectiveness. Farmer participation in problem diagnosis and field testing of technologies can provide useful information to researchers and result in useful products for farmers even if farmers do not gain control over the research processes (Farrington and Martin 1988). As the current extent of farmer participation in research is limited, particularly in national research centers, almost any small increase in participation will improve the effectiveness of many research activities.

Increasing pressures on research organizations to improve their effectiveness will lead to increasing collaboration with farmers, but constraints remain. More participatory research requires multidisciplinary work that may be difficult to organize; this was a constraint in earlier farming systems research (Farrington and Martin 1988). Some scientists are reluctant to learn from indigenous knowledge, and economists shy away from participatory methods because they do not always yield quantitative data. Scientific journals are less receptive to research based on participatory than traditional methods. As a result, major changes are still needed in both researchers' perceptions and the incentives that guide them.

Another constraint is that initial costs of participatory research can be high because travel and training budgets rise. In a project to develop pest control measures in Ghana, farmer participation increased project costs by 66 percent and accounted for 80 percent of researchers' time (Magrath et al. 1997). However, the Rwanda case shows that the extra cost can lead to higher returns by reducing the time needed to identify promising technologies. The cost per variety released actually fell in the Rwanda case (Sperling et al. 1993). Also, developing the farmers' own capabilities in developing improved pest management systems, or conducting field trials or even breeding can be a cost effective way to adapt technology to local needs where conditions are spatially diverse. Where participation may mean the difference between success and failure in developing technologies, there are no cost tradeoffs.

11. POVERTY IMPLICATIONS OF RECENT TECHNOLOGICAL DEVELOPMENTS: BIOTECHNOLOGY AND PRECISION AGRICULTURE

Scientific advances in recent years have led to important agricultural applications in the form of biotechnology and precision agriculture. The potential role of biotechnology in developing country agriculture is a vast topic with many uncertainties and the rapid generation of new information. Similarly, precision agriculture is an emerging technology with many unknowns. This review does not attempt to address these topics comprehensively; rather, it presents a brief overview of some major issues.

BIOTECHNOLOGY

In recent years scientists have taken advantage of new developments in genetic engineering, or biotechnology. "Biotechnology is in vitro manipulation of whole plant, cellular or molecular materials for the purpose of improving agricultural plants or processes" (Messer and Heywood 1990). Recent advances in biotechnology have come out of developments in cellular and molecular biology that help scientists to better understand and manipulate life processes. All living organisms are composed of cells that contain a substance called DNA in the chromosomes. Characteristics of living organisms are determined by information contained in DNA; the functional units of this information are genes. One of the important developments in biotechnology was the transfer of DNA from one living organism to another. DNA is naturally shared through sexual reproduction, but sexual reproduction can occur only between individuals of the same species. Genetic engineering offers methods to potentially transfer DNA between any living cells, whether from plants, animals, insects or bacteria.

These developments have been a boon to plant breeders, who have applied biotechnology to both hybrids and open-pollinated varieties. Cellular propagation or tissue culture, in which a few cells from a tissue can be used to raise a fully mature plant, has reduced the time taken in traditional breeding, and also enabled large scale multiplication of disease-free planting materials. Advances in molecular biology have greatly improved the ability of breeders to develop varieties with desirable traits. As a result, genetic engineering makes it feasible to change in the character of outputs, build disease and pest resistance, and increase yields. Biotechnology offers the potential to develop technologies for agriculture under less favorable conditions if varieties capable of withstanding moisture stress, for example, could be developed. The genetic potential for yields may be increased by identification and transfer of master genes that influence yields or through strategies to produce hybrids in new ways (Borlaug 1997; Herdt 1997).

Biotechnology is not without hazards apart from moral and ethical objections that people have to tinkering with life forms. Some of the hazards are increased use of herbicides where none are used presently, and the risk of passing on genes to other organisms through natural processes. Use of genes with virus resistance may lead to evolution of viruses capable of attacking a wide range of plants (Conway 1997). Industrial organization and intellectual property rights related to biotechnology are areas of major concern to developed and developing countries alike; these issues are addressed below.

PRESENT AND FUTURE PRODUCTS OF BIOTECHNOLOGY

Rapid adoption of genetically engineered plants in developed countries suggests that they may offer substantial benefits to commercial farmers. In 1998, 50 percent of cotton, 30 percent of soybean and 20 percent of maize planted in the US was genetically engineered (Lemaux 1999). Transgenic varieties available in the market contain genes with resistance to pests and diseases or tolerance to specific herbicides, usually those marketed by the same company that produced the seed. Most products in the market have been developed to reduce input use or target certain kinds of inputs. Herbicide tolerance is the most common trait, found in about 60 percent of genetically engineered plants, followed by insect resistance (30 percent) and virus resistance (10 percent) (Krattiger 1998).

Herbicide resistance can have ambiguous effects on input use. It can reduce herbicide use where herbicides are routinely sprayed before crop emergence. As herbicide resistant crops can be sprayed even after they are established, farmers can wait until the crop grows, assess potential damage from weeds, and spray only if and wherever needed. The use of herbicide tolerant soybeans in the US led to a 33 percent reduction in overall herbicide use in 1997 (Krattiger 1998). On the other hand, of course herbicide resistance also makes it possible to apply more herbicide than before. Byerlee (1996) points out that herbicide tolerance could have soil conservation benefits by enabling conservation tillage or no tillage systems whose greatest constraint is the need for weed control. Biotechnology has the potential to create resistance against effective but nontoxic herbicides, thus supporting environmental objectives.

Maize accounts for nearly a third of genetically engineered products. Wheat and rice products are expected to be on the market in the next few years, as is cotton with favorable attributes for processing; insect resistant tomatoes; vegetables and fruits with superior after harvest attributes; fast growing fish; and potatoes with higher starch content and virus- and insect-resistance.

Among the best known of the new transgenic plants may be those containing the *Bacillus thuringiensis* (Bt) plant protection protein transferred from bacteria. The gene builds insect resistance in plants by producing a protein toxic to insect pests. The obvious advantage is the reduced need for chemical inputs. A recent advance involves systems to activate the insect resistance gene only in the event of a pest buildup; this would have the advantage of making it more difficult for insects to develop resistance to Bt.

Another highly publicized recent development in biotechnology is the "terminator" gene that causes sterility in the offspring. This gene has yet to be incorporated into commercially available cultivars. Incorporating this gene into a genetically-engineered open-pollinated plant would make it more like a hybrid since farmers would have to replace the seed each year.[11] Accordingly it is of great interest to the private sector. It has also raised concerns that it could cause widespread damage if

[11] Biotechnology has been applied to both hybrids and open-pollinated varieties.

the sterility gene were unintentionally transferred from genetically-altered crops to other crops and plants in the ecosystem. Such concerns have stalled the application of the sterility gene pending further investigation.

POSSIBLE APPLICATIONS OF BIOTECHNOLOGY IN DEVELOPING COUNTRIES

Biotechnology has considerable potential to solve many problems plaguing developing country agriculture. One example is drought tolerance in millet, the most important food crop in arid areas of India and the Sahel. Drought tolerance is difficult to achieve through conventional breeding, but biotechnology may offer the hope of a breakthrough. Even more important would be to develop resistance against the parasitic weed Striga, which imposes a huge production constraint in Africa. Striga currently affects an estimated 8 million hectares in Africa—almost 40 percent of the total sorghum area—and annual yield losses are estimated to be worth over US$90 million (ICRISAT and FAO 1996). Its effects are long-lasting as each Striga plant produces many millions of seeds that can lie dormant in the soil for 15-20 years. Striga control (using a combination of genetic and management options) is an important research focus, but so far it has not been successful. Although several control options have been developed, most are either too expensive or otherwise impractical for smallholder farmers to adopt.

Biotechnology holds the greatest hope for major technical breakthroughs in increasing yield potential of green revolution crops and for developing varieties to extend the benefits of the green revolution to poorer and less well endowed regions. Although traditional breeding methods continue to make progress, they have reached their limits for raising yield potential of important crops such as rice. The possibilities that biotechnology offers may not be fully apparent as yet, and it is likely that progress will take place far more quickly than most people can imagine. To realize this one only has to consider the revolution in computer technology during the last 15-20 years, or the unexpected speed with which animal scientists were able to clone mammals. Biotechnology advances already achieved in other sectors have great potential for agriculture. Biotechnology is a complex topic characterized by numerous uncertainties and capable of evoking strong intellectual and emotional reactions. Some of the more difficult institutional issues are outlined briefly below.

Likely Implications of Biotechnology for Poor Farmers

Biotechnology has yet to have much impact on developing country agriculture. However, some projections can be made about its likely distributional effects between large and small farmers as its products spread in developing countries.

As introduced above, any biotechnology applications reduce the need for chemical inputs. This would likely increase the share of seeds in the total cost of inputs. It is not clear what would be the net impact on total costs, but it appears that it would be cost-reducing since farmers would need less of other, more cash-intensive inputs. For high-input commercial crops such as cotton this could help small farmers a great deal. Farmers may also be forced to buy seeds every season just as they do with hybrids, and this has caused some concern that poor farmers would find it difficult to adopt them. The same issues raised in Chapter 5 in this regard are applicable here.

Biotechnology might further favor the poor if it were used to increase the protein content of food crops they consume (Messer and Heywood 1990), or to reduce moisture stress in drought-prone areas (Hanumantha Rao 1994). Apparently these can be done much more easily through biotechnology than conventional breeding practices, under which both are very difficult (Walker and Ryan 1990; Byerlee 1996). Looking further to the future, if biotechnology could give plants the ability to fix nitrogen, the effect on poor farmers could be very large indeed (Hanumantha Rao 1994; Anderson et al. 1988a). Byerlee (1996) points out that such measures would require more technically advanced applications and so may not be feasible for several years.

Institutional Issues in Applying Biotechnology to Developing Countries

The most immediate constraints to harnessing biotechnology to help alleviate poverty in developing countries are not technical but institutional. To date, the benefits to developing countries have been limited because biotechnology is developed under institutional conditions quite different from those of the green revolution. While the green revolution was a public/nonprofit sector undertaking targeted explicitly at raising the food supply in developing countries, biotechnology is being developed mainly by the private sector in wealthy countries, with the explicit aim of earning a profit (Messer and Heywood 1990; Lipton and Sinha 1998). Private companies investing in biotechnology are likely to work where potential sales are large, patents are well-protected and risks are low. Most of the current crop biotechnology research is conducted in industrialized countries on crops that are economically important there. In the words of Lipton and Sinha (1998), "This drives out 'poverty-relevant' priorities: plant material is developed to resist herbicides, rather than moisture stress; to save labor costs rather than to raise yields and save land; and to retain seed patents in companies, not to empower farmers to multiply their own varieties. It also skews research towards industrial crops rather than poor people's staples."

Some technologies that would be particularly beneficial to developing country agriculture have proven difficult to develop so far. Transferring genes capable of nitrogen fixation or raising biological yield potential, for example, is not possible as of yet. Much of the development in pest and disease resistance and drought tolerance in temperate countries has limited scope for spillover to the tropics.

Biotechnology investments in the developing countries are small. Of the estimated $2.5 billion spent worldwide on biotechnology research and development, less than $75 million is in developing countries (Herdt 1997). Although trials were conducted in some developing countries such as Argentina, Chile, China and Mexico, they accounted for less than 2 percent of the total through 1995.

This imbalance in biotechnology investments and priorities has potential implications for agriculture in developing countries, particularly on resource-poor farmers and regions. Biotechnology may favor farmers in the developed countries by reducing input costs, mainly herbicides and pesticides (Herdt 1997). Further advances could enable developed countries to grow or substitute for traditional tropical exports, thus reducing developing countries' export incomes (Lipton and Sinha 1998).

Because of private control of biotechnology and the small market in developing countries, it will be slow to move to developing countries. Developing countries should invest in the capability to carefully assess new genetic materials, and devise arrangements to gain access to those that are useful. For example, they can undertake to buy genes from the private sector to incorporate in their own germplasm collections. International organizations and governments need to work with the private companies to develop institutional arrangements to transfer useful biotechnology products and skills to developing countries. Some interesting collaborative efforts have been initiated with support from private companies and international donors. Monsanto has donated to Mexico the genes conferring resistance to important potato viruses, and transformed potatoes are being field tested (Herdt 1997).

Several authors make the point that developing countries should pool their resources to invest jointly in biotechnology capability, (Byerlee 1996; Shanmugaratnam 1997), and some such collaborative efforts are underway. A project to develop virus-resistant papayas with delayed ripening has been developed as a collaboration between five countries in Southeast Asia and several private companies and universities (Krattiger 1998). In addition, public-private initiatives such as the International Service for the Acquisition of Agri-Biotech Applications (ISAAA) are facilitating technology transfer. IARCs are also playing an information dissemination role.

PRECISION AGRICULTURE

Precision agriculture refers to carefully tailoring soil and crop management practices to physical conditions on each field (Johannsen 1995). Farmers have always varied their management practices according to spatially varied plot characteristics, but advances in computer and remote sensing technology are creating new opportunities to do so with increasing precision. The critical technologies for precision farming are remote sensing, geographic information systems (GIS), and global position systems (GPS). GPS enables farmers to carry out site-specific management by letting them know exactly where they are on the plot, while GIS enables them to map crop inputs and outputs to analyze site-specific differences in yield response. For example, if agricultural machines are outfitted with a GPS and variable rate input applicators, it will be possible to adjust soil management and input levels spatially based on recommendations generated through the GIS-based analysis. Combine harvesters, meanwhile, can use the GPS and sensors to indicate spatial variations in crop yields and thus provide important yield response information to the GIS database. Remote sensing can also generate information for the database, and it can provide early warning about the emergence of possible crop stresses. Ultimately these data collection mechanisms and crop management functions can all be linked by the same computer system so that site-specific management becomes automatic.

Lowenberg-DeBoer and Swinton (1996) caution that precision agriculture is an infant technology whose possibilities are just emerging. For now the high costs of some of these approaches limits their application, but continued technological advances means that changes will take place rapidly. Farmers will have to improve their own human capital in order to understand the new opportunities and make good investment decisions. Also, institutional innovations will be needed to help farmers obtain precision farming information at an affordable cost. A key factor in this regard concerns the fact that there are likely economies of scale in the collection, analysis and management of data that drives precision farming. Leiva et al. (1997), for example, found in an ex ante analysis of early precision farming practices in England that they would be much more profitable on an 800 ha farm than a 150 ha farm. They suggested that smaller farms would probably need to hire the services of contractors or consultants in order to afford the technology. Private services are likely to emerge to manage data and program farmers' machines for optimal spatial variation in management practices.

Even large farms in developed countries probably will have to pool data in order to realize the full benefit of precision farming. This is because discovering optimal practices will require comparing the performance of many farms using alternate approaches. Lowenberg-DeBoer and Swinton (1996) suggested that data could be pooled through four possible organizational arrangements: 1) agricultural input manufacturers and suppliers, 2) independent data management companies, 3) non-profit data management groups, and 4) universities (or government services). Each alternative has its advantages and disadvantages; Lowenberg-DeBoer and Swinton pointed out that data management by private input suppliers raises questions of conflict of interest.

THE POTENTIAL OF PRECISION AGRICULTURE IN DEVELOPING COUNTRIES

Applying precision agriculture in developing countries will involve a variety of challenges. Most importantly, precision agriculture most likely involves economies of scale and the need for data sharing among farmers even in large-scale, developed country agriculture. For developing countries the problems of scale economies and data pooling would be obviously be much more substantial. Even most relatively large farms will be tiny compared to the scale of the American and European farms on which precision agriculture is being tested. Computerized agricultural machinery with GPS and variable input applicators is also much less realistic in developing countries in the near future. On the other hand, it may be less important given that the tiny plot size typical in developing countries makes spatial variation much easier to manage there. In fact, tropical drylands and uplands are characterized by much greater spatial variability than temperate zones (Walker and Ryan 1990). Small-holder farmers are already intimately aware of variability within their holdings and pursue diverse management practices accordingly (Dvorak 1988, Chambers 1997, N.S. Jodha, personal communication).

This suggests that the challenge of applying precision agriculture in developing countries may be more about generating and disseminating better information about how to exploit spatial variation rather than finding ways to automate identification and management. Better information about temporal factors would also be of great benefit. Weather forecasting, for example, is something that developed country farmers take for granted but that farmers in developing countries have little or no access to. Warning systems about outbreaks of pests, diseases and other stresses would also help farmers, as would better market intelligence. In short, developing countries also stand to gain a great deal from information-based agriculture, but the precise needs may differ.

Generating and disseminating information for precision agriculture in developing countries will require greater institutional challenges than in developed countries. Relatively large farms may have no inherent advantage over small ones in collecting and analyzing data because their scale will still be very small in absolute terms. Specialized service providers will have to manage data and provide information to farmers. Educated farmers may benefit by understanding the management practices better, and those with more influence and better connections may benefit from superior access to information. Devising institutional arrangements for equitable access will be critical to promoting precision agriculture without harmful income distribution impacts. The problem is closely related to the broader need for better extension services; it is not easy to predict what arrangements would be most effective.

12. METHODOLOGICAL ISSUES IN ASSESSING THE IMPACT OF AGRICULTURAL RESEARCH ON POVERTY ALLEVIATION

Measuring the impact of agricultural research on poverty alleviation is complicated. Care is needed to design research approaches to sort out indirect, complex relationships and attribute causality among numerous factors. There are many kinds of agricultural research and many kinds of poverty impacts, so it is also critically important to be very clear about precisely what is being studied. This chapter outlines some relevant issues; as is the case with the rest of this review, the intention is not to provide an exhaustive discussion. Rather, some basic approaches are presented along with specific methodological recommendations for certain types of case studies. The focus is on evaluating the poverty alleviation impact of the technologies that research produces.

SETTING UP THE RESEARCH

Defining Standardized Indicators of Poverty and Poverty Alleviation

Chapter 2 showed that poverty is multi-faceted and difficult to characterize comprehensively. Typically it is characterized in terms of monetary income, but other measures of the quality of life are also important poverty indicators. These may address physical well-being, such as health and nutrition status, or social status indicators such as the opportunity to participate in society, influence decision makers, and make one’s own decisions. For all these diverse indicators, poverty status could be chronic or transitory, so one important indicator of poverty status is the risk of falling into poverty even on a temporary basis.

As explained in Chapter 2, this study focuses mainly on poverty in monetary terms and, to a lesser extent, in terms of nutritional status. While recognizing the importance of other measures of poverty related to social status, opportunity, and influence, it does not address them explicitly because it would not be possible to do them justice given available resources and the shortage of information. Some of the discussion here has relevance to broader poverty measures, but it is incomplete. A second review will be commissioned to examine in detail the relationship between agricultural research and these broader measures of poverty.

Given the complexity of poverty and the many ways to characterize it, any study of poverty alleviation impact must make clear at the outset what measure of poverty it is using. In a set of case studies such as those being conducted under this research project, it is also important that all of the studies use the same definition and a common set of measurable indicators by which to judge performance.[12] This is essential to achieve comparability across the studies and thus draw general conclusions and lessons for the future.

Developing Research Questions, Hypotheses and a Conceptual Framework

As simple as it sounds, developing good research questions is a critical step in undertaking an assessment of a relationship as complex as that between agricultural research and poverty alleviation. Given the diverse definitions of poverty, the multiple factors that contribute to it and the indirect nature of causality, unclear research questions will undermine any impact assessment effort before it even begins. Developing a good research framework involves several steps.

First, what is the researchable issue in question? What knowledge will it generate—is it worth devoting resources to? Given limited research budgets and the complexity of analysis, the researcher must be fairly certain that the study will yield useful information, whether in terms of developing improved methodology for other studies to use or a better understanding of an important, policy-relevant problem.

Second, the researcher must develop one or more hypotheses about the nature of causal relationships in the case study in question. Hypotheses reflect what the researcher

[12] A word's *definition* is its precise meaning, whereas an *indicator* is a characteristic or attribute that indicates the presence of some feature or condition of interest. In attempting to assess poverty impacts, developing good indicators of poverty is more important than agreeing on a precise definition of poverty. This is partly because indicators are measurable, but also because they can be clearly specified even if what they indicate is defined only vaguely.

thinks about such causal relationships. Testing whether the hypotheses are correct then becomes the focus of the study. Developing good hypotheses disciplines the researcher to make sure the most important research questions are being asked, to think through what data and analytical methods will be needed to answer them, and to distinguish between relevant and irrelevant information. Developing hypotheses is important whether the study will use quantitative or qualitative analytical tools.

The key word here is "develop." Useful hypotheses are generated and refined on the basis of a great deal of background information. Sources of information should include a review of the existing literature and as much knowledge as possible about the current research context, including its specific objectives. Reviewing the literature enables the researcher to draw on existing theoretical and empirical knowledge, and to avoid making mistakes that others have already discovered. Understanding the local context ensures that the researcher does not get carried away with enthusiasm over a particular issue in the literature that may or may not be relevant to the case in question. This means, for example, that in a village level study of the effects of a new technology on the distribution of income, the researcher should visit the village and ask open-ended questions about the problem before, or in the process of, developing hypotheses about causal relationships. The researcher should continue to refine the hypotheses as better information becomes available.[13] In short, good hypotheses evolve over time before any widespread survey work starts. Researchers need to invest time in this process.

The researcher can then build a conceptual framework about the hypothesized causal relationships. At least two steps are important here. First, the researcher must appreciate how direct or indirect the relationship is between technology and income distribution. For example, in the case of modern varieties the connection between the research output, its adoption and then its impact is direct, if complex and conditioned by other factors. But in the case of an improved soil conservation practice the connection may be highly indirect. First, it may be difficult to distinguish between the new technique and some local practice. Second, assessing the impact of the practice on soil erosion will

[13] Miller et al. (1994) provide a useful causal analysis framework for developing hypotheses.

be very difficult, since erosion is caused by numerous agronomic and climatic factors. Even then, relating erosion to changes in productivity is never easy. Researchers attempting to assess research-poverty linkages must have a good understanding about the nature of the link between research output and poverty outcome in order to assess whether the available data and analytical tools will be sufficient to establish causality between research and impact.

The second step in building the conceptual framework is to identify possible causal forces other than agricultural research. These may include such factors as economic policies, social relationships, population growth, etc. Explicit consideration of such potentially confounding factors will help the researcher design the analysis in such a way that successfully captures the effect of agricultural research as opposed to other factors. Even if isolating the different effects is not possible, at least the researcher will recognize the limitations of the analysis and the need to take care in attributing outcomes among multiple causal factors.

In fact, Casley and Kumar (1988) suggest that usually there are so many confounding factors that researchers cannot establish causality unequivocally; they settle for "a reasonable indication of a strong association between a set of variables in a temporal sequence, which is logically justifiable." Casley and Kumar caution that unrealistic expectations may lead to unrealistic evaluation designs that require too many resources and ultimately are not successful.

Data Requirements

Data for impact assessment has three purposes: description, explanation and prediction (Casley and Kumar 1988). These three uses of data follow in logical order, with each step building on the previous one. Descriptive data analysis addresses questions of what, who, when and where; for example, what are the characteristics of a technology, and what attributes describe households that adopt it? Explanation then proceeds to examine causal relationships of how and why; for example, why do some households adopt the technology but not others? How does differential adoption affect distribution of income? A reasonable understanding of causal relationships then lays the groundwork for predictive analysis, or ex ante assessments of likely impacts. For example, based on what we know about adoption patterns of technologies with certain characteristics and the consequences for income distribution, what can we expect from introduction of another technology, or of the same technology in a different socioeconomic context?

Data requirements for conducting such analysis include the following:

Outcomes. In a study of the impact of agricultural research on poverty alleviation, the outcome in question is poverty or poverty alleviation. As mentioned above, poverty is difficult to define, let alone measure, so in practice the outcomes are indicators of poverty. A variety of concrete indicators can be considered. For the case of the effects of new technology on poverty, a sample of indicators includes the following:[14]

- The technology's effects on income levels for different types of households. This depends more specifically on the effects on food prices (particularly for foods important to poor people), wages and labor demand, and farm revenues for adopting and nonadopting households.
- Its effects on nutritional indicators such as height for weight, height for age, etc., particularly for the most vulnerable people, such as infants and pregnant and lactating women.
- Whether the technology smooths household consumption and income streams. (This is important because if income is distributed evenly over time it will reduce the risk of falling into poverty during lean seasons or lean years.)
- The effect of the technology on the allocation of children's time. (This affects the opportunity cost of education and thus the long-term prospects for escaping poverty.)

[14] This list draws on suggestions made by participants in the IFPRI Workshop May 12-14, 1999, and especially by Peter Matlon.

- The effect on women's time use, which affects both women's well-being and that of others in the family if it changes women's time allocated to other important activities.
- Whether there are health risks associated with the technology.

These diverse indicators are presented just to give an idea of some of the possibilities. Not all of them will be relevant for every kind of technology, and it will not always be possible to link a technology to every indicator.

Background Information and Determining Factors

In a study of the impact of agricultural research on poverty, the most obvious determining factor is the characteristics of the research output, in this case a new technology. What is required to use the new technology? How does it perform under different conditions?

Evaluating the poverty alleviation impact of a given technology requires information on conditioning factors such as household-, community-, and regional biophysical and socioeconomic conditions. Household conditions include social status, physical, financial and human capital assets, access to markets and services, etc. Community-level factors include climate and social and physical infrastructure conditions. Regional or national conditions include government policies affecting all communities.

The research process may also have important implications for the impact of research on poverty alleviation. How was the technology developed, based on whose priorities, and with what objectives? Did farmers or consumers have any input? Could they voice their priorities and, if so, did these priorities carry any weight? How do the answers to these questions affect what kinds of technologies were developed and the subsequent impacts on poor people's welfare? The example of bean selection and distribution in Rwanda in Chapter 10 showed that farmer input in varietal release changed the outcome considerably. Many other examples show that farmer participation can improve both research and extension outputs, and a smaller set of examples shows that farmers can strengthen their own problem-solving skills and stimulate innovation. Even so, to date little research has been conducted on how the research process affects either productivity or poverty alleviation outcomes. Impact assessment research can make a positive contribution by attempting to identify the role of the research process.

Before-and-After and With-and-Without Data

In order assess impact of a new technology on poverty, the researcher must be able to obtain information about the counterfactual: what would conditions be like if the technology had not been introduced? Of course this cannot be known with certainty, but researchers can take two approaches to address the question. First, they can use “before-and-after” information from the location where the technology was introduced; in other words, they need to compare data on current conditions with *baseline* data on conditions before the technology was introduced. There are two problems with this approach. First, often baseline data are not available. In this case the researcher may be able to construct baseline data based on respondents’ memories, but this is likely to be error-prone for many types of important information. It may be easy to learn, for example, when a new employment program was initiated or when a technology was introduced, since these are sudden, infrequent events for which approximate dates are sufficient. It may be impossible, on the other hand, to obtain information on factors that change frequently, such as the household’s grain yield or number of employment days. And it will not be possible to obtain data on factors that require current measurement, such as anthropometry. The second problem with the use of baseline data is that the researcher must take care to distinguish between the poverty impact of the new technology with that of other factors that also have changed over time. For example, if the introduction of the new technology coincided with the initiation of regular bus service from the village to a nearby town, it would be important to distinguish the effect on wages of demand for labor under the new technology versus the effects of greater access to employment in town. Other cases may be much more subtle, making identification of causal relationships very difficult.

The second method for obtaining counterfactual information is to obtain “with-and-without” data, i.e. to compare conditions in a location where the technology was introduced with another where it was not. Data availability will not be a problem with this approach, but there will be analytical problems. In short, even if the two locations are similar, there are likely to be underlying reasons why the technology was adopted in one location but not the other, and the researcher may or may not be able to determine them. Care will be needed to distinguish between the impact of the new technology on poverty alleviation versus the impact of the underlying conditions that led to differential adoption. For example, if adoption in one location depended on access to markets and government services that were absent in the other location, these underlying factors may be more important than the new technology in alleviating poverty. The key analytical challenge associated with this problem is to design the sample in such a way that the "with" and "without" groups are randomized, so that there are no unobserved factors that systematically distinguish them. Approaches to do this are discussed below.

While the before-and-after and with-and-without approaches both have weaknesses, if they can be combined and the with-and-without groups are randomized, then the weaknesses can be overcome. This approach, described in more detail below, is the best way to determine impact (if not precise causality).

QUANTITATIVE AND QUALITATIVE DATA AND METHODS

Both quantitative and qualitative data have important roles to play in assessing the impact of agricultural research on poverty alleviation. A simplistic distinction between qualitative and quantitative data is that quantitative data are numeric, while qualitative data are best described in words (Casley and Kumar 1988). However, some qualitative data can in fact be recorded in numbers, so a better characterization of qualitative data is based on the way they are collected (Chung 1997) and used. She lists four key characteristics that distinguish qualitative methods from quantitative, as follows.

1) The qualitative approach is less structured. Data collection is based on flexible discussions, both with individuals or groups and with either a broad or narrow agenda. This flexibility enables the researcher to go into greater depth on any particular topic of interest. Qualitative surveys may use visual tools

associated with participatory rural appraisal (PRA), but not necessarily. Quantitative surveys, on the other hand, are highly rigid.

2) Qualitative data collection relies more heavily on iterative interviews, meaning that there is an ongoing opportunity for the researcher to return to a given respondent to ask new questions, seek clarifications, etc. In quantitative surveys, each respondent is approached only one time for a given piece of information, with no opportunity to expand on interesting points.
3) Qualitative researchers rely on multiple sources and methods, or triangulation, to assess the accuracy or authenticity of a given finding. This can involve asking the same question of multiple respondents, or using different techniques to obtain the information, or using different researchers. The focus is always on the views of insiders. Quantitative researchers, meanwhile, conduct their work with an outsider's perspective, developing models based on variables that they define. Critics suggest that survey researchers devote insufficient attention to understanding the local meaning of the variables they use, leading to reduced internal consistency.
4) Qualitative and quantitative researchers aim to make different kinds of generalizations. Qualitative researchers typically focus intensively on a small number of cases; they choose their samples purposively, not randomly, in order to examine cases with characteristics of interest based on prevailing theories or empirical evidence of the subject in question. They try to identify conceptual and theoretical extrapolations or analytic generalizations (Haberkorn 1988, cited by Chung 1997). These analytic generalizations are not conclusions but working hypotheses that can be further examined in other studies. Quantitative survey researchers, on the other hand, usually use a large, random sample. The aim is to generalize the statistical conclusions from a given random sample to the population as a whole.

According to Chung (1997),"The principal advantage of (quantitative) surveys is that they can be administered to large numbers of individuals (or households) using standardized methods. Standardization across observations makes it possible to aggregate poverty measures and to make statistical comparisons among individuals, households, regions and time periods. In contrast to qualitative methods of inquiry, quantitative data (in their raw form) are derived from questions that ask "what?" and "how much?" The underlying assumption of this approach is that, if the researcher knows *what* exists or *how much* exists, then he or she can use statistical models of behavior to understand *why* it exists."

COMPLEMENTARITY OF QUANTITATIVE AND QUALITATIVE METHODS

Quantitative and qualitative methods are highly complementary because their strengths correspond to different aspects of the research problem. Qualitative data are particularly valuable in the early stages of research, for example in identifying research issues and developing hypotheses. The use of loosely structured, open-ended discussions, for example, allows the researcher to begin an investigation with minimal preconceptions. Particularly if they are based on participatory methods, such discussions generate information quickly and help gain a preliminary understanding of the situation. Successive rounds of qualitative inquiry can take a sharper focus to probe people, topics and relationships of interest, generating knowledge that leads to more clearly articulated research questions and hypotheses. This process can help determine whether the problem warrants further research using quantitative methods. If so, then it sets the stage for effective quantitative data collection and analysis which, in contrast to qualitative research, must address a narrow set of rigidly defined questions from the outset. Collecting and computerizing quantitative data is inflexible, time consuming and expensive, so keeping a narrow focus minimizes the time and cost of this process. Many resources will be wasted if quantitative data collection is too broadly focused or if it is narrowly focused on the wrong set of questions, or if it asks the questions in ways that are not clear to respondents.

Along these lines, Lipton and van der Gaag (1993) recommend a hybrid of anthropological and economic approaches in which collection of detailed ethnographic data over time feeds into a process of developing and testing hypotheses about the community and institutional contexts in which particular events or changes are likely to help or harm the poor. They cite Bliss and Stern (1982), Bell (1977), Hart (1986), Wade (1982), Pryor (1977), Bardhan and Rudra (1981), Dasgupta et al. (1977) and Connell (1976) as studies that pursue such methodological approaches.

Qualitative research remains important both during and after the quantitative stage, because it helps researchers correctly interpret quantitative findings. Quantitative and qualitative analysis may even yield different findings. Both are susceptible to misinterpreting data. For example, a qualitative investigator may be overly influenced by particularly intriguing cases that may or may not be representative. Quantitative analysis, meanwhile, may focus too much on mean values and not enough on variation across the sample, or it may be overly influenced by large outliers. Combining quantitative and qualitative analysis will help researchers overcome such problems by pointing to paradoxical findings that require more detailed investigation.

A study by Chung et al. (1999) showed vividly how detailed qualitative information could add insights to a quantitative study. A thorough quantitative survey of food consumption patterns completely failed to identify the importance of wild foods in people's diets in Indian villages. But ethnographic data showed that in one village, poor people augmented their diets during a brief, food-scarce period of the rainy season by consuming edible "weeds" that they gathered while working as hired laborers. Weeding employment thus conferred additional benefits beyond wages, and any technical "improvement" that reduced labor demand for weeding potentially could harm the nutritional status of these poor people.

QUALITATIVE METHODS AND PARTICIPATORY RESEARCH

Qualitative approaches are also essential for increasing local participation in research because of their flexibility, the value they place on insiders' perspectives and knowledge, and their emphasis on iterative learning. The use of visually-based PRA methods, a subset of qualitative research tools, is especially useful because it can enhance communication between researchers and local people, and it can help stimulate people's analytical skills. The list of PRA methods is long and growing all the time. Some of them include participatory mapping, matrix ranking and scoring, time lines and trend analysis, and seasonal calendars. The critical principle underlying all these methods is that the local people carry them out while the researcher only facilitates the process. Drawing analytical diagrams on the ground, where everyone can see them and contribute to producing them, helps stimulate discussion among people. Good sources of information on such methods are PLA Notes (formerly RRA Notes, 1988-1999) and Pretty et al. (1995).

Participatory monitoring and impact assessment is a useful approach for identifying important information that outsiders might miss. It also has the potential to expand local people's ability to analyze causal relationships and identify or develop possible solutions to various problems, and in that sense it can be empowering. However, participatory monitoring and impact assessment are very complex, and great attention must be paid to the usual questions about "who participates" and "impact on whom" (Guijt 1998). It is difficult to ensure that all members of a community contribute to such an exercise, particularly the poorest and weakest people about whom such an assessment would be concerned in the first place. One obvious point is that if agricultural researchers are able to build good working relationships with communities to carry out participatory research, they can work with the same communities to conduct participatory monitoring and evaluation. Similar organizational skills and methods will be needed for both research and monitoring and evaluation, and there will be important research methodology advantages. Obtaining baseline data and isolating the relationship between technical change and its effects will be much easier than elsewhere.

Good Practices in Qualitative Methods

Chung (1997) lists four broad principles for conducting good qualitative research that can be summarized as follows.

1) The research team must be diverse, containing people with a variety of skills who can understand different issues and look at the same problems from different perspectives. Investigators must be able to understand (and should be interested in) the research topic, think on their feet, and write well in prose. Experienced survey investigators may be the wrong people for this work because they are not trained for such skills.
2) Even though qualitative data collection is only loosely structured, it requires substantial organization and planning to address the right issues and interview the right people.
3) Principal investigators must be involved at all stages. Since the data collection methods are only loosely structured, constant input is needed to evaluate the process, adapt methods as needed, and help investigators record and interpret information. Researchers cannot simply train investigators to use the questionnaires and leave them to collect the data, as quantitative researchers often do. Qualitative work is only as good as the capabilities of the person who collects the data.
4) Because qualitative methods can be so time-consuming, it is important to set boundaries on their use. They should focus on research questions most suited to qualitative methods, and where quantitative methods are weakest.

SAMPLING BIAS IN QUANTITATIVE RESEARCH

As introduced above, assessing the impact of new technology on poverty alleviation often requires distinguishing between the impact of the technology itself versus the impact of underlying factors that cause differential adoption in the first place, but also have impacts on poverty alleviation through other avenues. This problem is not straightforward. For example, consider a case in which an NGO has introduced a new agronomic practice in the villages where it works. The researcher would then like to compare progress in alleviating poverty (or simply in raising agricultural productivity) in the village that adopted the practice to that in a neighboring village that did not. The question here is whether the NGO village has other characteristics besides the new technology that may contribute to agricultural productivity or poverty alleviation. There are several reasons why this might occur. First, perhaps the NGO selected the project village because its residents were hard working and willing to cooperate with each other. These factors could lead to better performance in poverty alleviation or agricultural productivity even without introduction of the new technology, and the researcher has to keep this in mind. Second, even if the NGO selected the program villages randomly, it may be conducting other programs, for example to generate income or improve health care, those are absent from the neighboring village. Third, there may be differences between the program and nonprogram villages, or the households within them, that the researcher does not observe but that may have independent effects on agricultural productivity or poverty alleviation.

This problem is important in both quantitative and qualitative research; all researchers need to be aware of the interaction among multiple causal forces. In quantitative research it is particularly problematic because statistical analysis aims to generalize findings for a given sample to the entire population. If the sample is not drawn randomly, or if there are hidden relationships determining between relationships of interest, the findings will be biased, i.e., the statistics estimated for the sample will not represent those for the entire population.

Quantitative Methods for Overcoming Sampling Bias

In an econometric framework, consider two equations, one that explains whether the village is selected for the program, and a second that explains the outcome variable of interest, in this case some indicator of agricultural productivity or poverty alleviation. The program status (the dependent variable of the first equation) is one of the explanatory variables in the second equation. An estimation problem arises because the error terms of the two equations are correlated. Econometric estimation that ignores this correlation will yield biased estimates.

As mentioned above, solving this problem requires randomizing the “with program” and “without program” groups. The most fundamental approach involves sampling the respondents in a way that eliminates the bias, but this is not always possible. The idea is to control for the sources of bias in the same way that a laboratory scientist would set up an experimental design. For example, Pitt et al. (1996) conducted a study of the poverty alleviation impact of the Grameen Bank and similar credit programs in Bangladesh. They surveyed five types of households:

- participating households in program villages
- households in program villages that were eligible to participate but chose not to
- households in program villages that were ineligible to participate (because they owned too much land)
- nonparticipating households in nonprogram villages that would have been eligible according to program rules
- nonparticipating households in nonprogram villages that would not have been eligible

This approach sets the stage for a “natural experiment” (Pitt el al 1996) in which the program placement is not correlated with observable determinants of the poverty alleviation outcome. The explanation of how this works is highly technical; more information on this approach is available in Pitt et al. (1996) and a series of related studies based on the same data set.

De Janvry (personal communication) described another quasi-experimental approach. In a Southeast Asian country, certain households and/or villages nationwide are eligible for a government poverty alleviation program, but the program has not covered everyone yet. Also, those who have yet to receive benefits do not yet know that they will be covered, so there is no reason why the existence of the program would change their current behavior (in anticipation of future coverage). This sets the stage for a natural experiment involving eligible households or villages that have been covered, eligible households or villages that have yet to be covered, and ineligible villages.

This kind of approach has not been used much in social science research. This is partly because the opportunity is not always available, but also because more researchers have not made the effort. Opportunities are probably more abundant than one would immediately realize, since government programs often specify the program coverage long before the work is actually conducted.

Pitt et al. (1993) described a quantitative approach in which they take advantage of the presence of both with-and-without and before-and-after data. They studied a family planning program in Indonesia in which preliminary analysis showed that villages where the program had operated actually had higher fertility rates than those where it had not. One could jump to the conclusion that the family planning program had failed miserably, but Pitt el al explained that the difference was not surprising given that the program consciously worked in villages where the fertility rate had been higher to begin with. In the absence of the family planning program, the fertility difference between the two sets of villages could have been even greater. Using their rich data set, the authors' analytical strategy was to relate the *changes* in fertility rates before and after the program period to *changes* in explanatory variables (hypothesized causal factors and background conditions) during the same period, and compare these between program and nonprogram villages. This approach eliminated from the analysis information about both the pre- and post-program fertility levels and values of explanatory variables, isolating the pure effects of the family planning program and other changes in conditions.

This approach is sound, but the necessary data may not be available. Also, if the time period of the study is relatively short and the number of villages or households is relatively small, many potentially important variables may not have changed during the study period. Kerr et al. (1998) faced this problem in a study of the impact of watershed development projects in India. The study aimed to distinguish between the role of watershed projects and that of infrastructure conditions in raising agricultural productivity and improving natural resource management conditions. Very few infrastructure variables had changed during the study's ten year time period, so the Pitt et al. (1993) approach was not feasible.

In the absence of baseline data, the researcher must obtain with-and-without data, i.e. in both villages with and without technological change in the present context. As mentioned above, the analysis will have to take steps to ensure that observed impacts are due to the technical change as opposed to some underlying factors that determined the technical change. The simplest standard econometric approach in this situation is to undertake the analysis in two stages.[15] The first stage is a probit analysis in which the dependent variable is equal to one for adopting households or villages (or those covered by the program) and zero for nonadopters or those not covered. The analysis attempts to identify the factors that explain adoption, and it calculates for each household or village the probability of adopting the technology or being selected by the program given its values of all the explanatory variables. These probabilities replace the unobserved variables and then are treated as if they were the known value of the unobserved variable. The utility of this approach depends on the nature of the problem at hand. For some applications it is simple to execute using standard statistical software, and it yields theoretically sound results. For other, more complex problems, it yields accurate statistical correlations and regression coefficients, but identifying their correct statistical significance (to determine whether they represent the greater population, not just the sample) requires complex mathematical adjustments (Murphy and Topel 1985). In this case, even more than in standard econometric analysis, it is critically important to consider the econometric findings as indicative and to augment them with a good qualitative understanding. Vela (1997) and Maddala (1983) provide more discussion of such models.

[15] A more complex approach is to estimate the first and second step models jointly using full information maximum likelihood estimation. Use of this approach is limited by its computational difficulty.

Implications for Qualitative Research

The most important step for qualitative researchers is to be aware of the problems of nonrandom program placement and the correlation among different determinants of outcome variables, and to consider them explicitly when selecting the sample, collecting data and interpreting findings. A good example of the kinds of factors to consider comes from the study of Indian watershed development programs by Kerr et al. (1998), mentioned above. This study sampled villages covered by a variety of government and NGO projects along with control villages with no project. The study showed that for most outcomes of interest (related to agricultural productivity, natural resource management and poverty alleviation) NGO project villages performed better than others. However, closer inspection revealed that both types of programs selected villages on the basis of certain factors that were important to them. This made it difficult to distinguish between the effects of project inputs and underlying village characteristics on outcomes.

What can the qualitative researcher do under these circumstances? The most obvious requirement is to be aware of the program selection rules and the differences in conditioning factors across villages. The qualitative researcher needs to collect background information on the conditioning factors, just like the quantitative researcher. The qualitative researcher can also draw on the principles of quasi-experimental design in selecting a purposive sample. The two approaches described above from Pitt et al. (1996) and de Janvry could guide purposive sampling, for example. Even if such "natural experiments" are not possible, even thinking about what they would require will help the qualitative researcher consider what traits to consider in designing a purposive sample. In the end, as mentioned above, the careful qualitative researcher will end up with a set of working hypotheses about the relationships in question.

QUANTITATIVE MODELING APPROACHES TO EXAMINE MULTIPLE, INDIRECT EFFECTS OF TECHNICAL CHANGE

As discussed in Chapters 4-8, technical change will have a range of effects on farm profits, employment incomes and food prices. Some of these effects are direct and immediate while others are indirect and take time to be realized through feedback effects from one part of the economy to another. Also, many farm households are affected simultaneously by such changes because they both produce food and sell it, and they both hire in and hire out labor. This section discusses a variety of modeling approaches useful for analyzing the effects of technical change under these conditions. It draws heavily on Sadoulet and de Janvry (1995); more details can be found there and in other references listed.

Household Models

In standard economic theory decisions regarding agricultural production, food consumption and labor allocation are analyzed separately, just as they were presented separately in Chapters 5-7. The basic microeconomic models for each of these activities are characterized as follows:

- Producers maximize profits subject to a production function, i.e. constraints about what they can produce with given available resources.
- Consumers maximize "utility" or welfare buy purchasing goods and services subject to what their budget can afford.
- Workers allocate their labor in such a way as to maximize utility in how they spend their available time, subject to the need to use some of that time to earn income.

The household model, on the other hand, combines these three processes into a model in which the household maximizes utility subject to the joint constraints of the production function, the budget and the available time. The key assumptions of the model are that there is a tradeoff between home time and the consumption of goods that require income, and thus labor time to produce. Home time is not simply leisure but also includes family maintenance activities such as cooking and washing, reproduction activities like raising children and taking care of older people, social relationships within the family or community, such as festivals and religion, and finally leisure. Working to earn income requires tradeoffs with all of these activities.

The specification of the household unit varies by culture; it can range from a single-family unit to an extended family network of the type common in sub-Saharan Africa and referred to briefly in Chapter 5. The only modeling requirement in this regard is to be explicit about what unit is referred to. Also, standard household models assume there is only one decision-maker, or that everyone in the household shares the same objectives and interests. Other modeling approaches allowing bargaining between household members are needed to examine intrahousehold distribution issues. They are discussed in Haddad et al. (1997).

Household Models and Market Failures

The use of household modeling can be divided into two distinct situations: when all markets operate efficiently, and when at least one important market fails. Each of these is discussed in turn.

When all markets work efficiently, production and consumption decisions are linked only through the level of farm income achieved through production. Decisions regarding each can be seen as separate and sequential: the household produces as much as possible and then makes consumption decisions based on the resulting net income. In this sense the household is much like a modern, western household with salaried income, except that agricultural product prices simultaneously affect income and the cost of consumption.

With perfect markets, solving the household model yields the following measures of interest to the situation of a household that engages simultaneously in food production and consumption and wage employment:

- elasticity of consumption for food with respect to the price of food
- elasticity of demand for home time with respect to the wage rate
- elasticity of marketed surplus with respect to the price of food

Under these conditions, there is no need to use the household model if the analyst is only interested in production decisions. It can be useful for linking consumption decisions to production levels, but it is only worth the considerable effort of doing so under the following circumstances: 1) price changes in the product of interest result in large changes in farm profits, 2) farm profits are a large share of income, and 3) demand for the product in question has a large income elasticity. Unless these three conditions hold, one might as well examine production and consumption separately for the case without market failures.

The situation becomes more complex when markets fail. With credit market constraints, risk and risk aversion, high transaction costs and shallow local markets, price bands widen between what the household would pay to buy a commodity or service and what it would receive by selling it. After a point the commodities effectively become nontradable and the household becomes self-sufficient, analogous to the case of the national economy described in Figure 7.4. The household's production and consumption decisions are no longer made separately; rather, the household behaves as if there were a market for the good within the household. Factors conditioning the household's demand (as its consumer) and supply (as its producer) determine the commodity's opportunity cost, or shadow price.

Under these conditions the household model is essential in theory. However, in principle, the complications of using the approach suggest that it is only worth it if the good for which the market fails is important, and the price bands mentioned above are large. Tests for when to use a household model, basics of how to construct it and extensions to more complex situations, such as intertemporal decision-making and decision-making under transaction costs, are described in Sadoulet and de Janvry (1995) and Singh, Squire and Strauss (1986).

Social Accounting Matrices (SAMs)

The agricultural sector is closely linked to other economic sectors as explained in Chapter 8. Economy-wide or multiple-market analyses are needed to trace both direct and indirect feedback links across sectors. A social accounting matrix (SAM) is an economy-wide model that tracks all kinds of transactions among sectors and institutions. It is consistent, meaning that for every income in one part of the economy there is a corresponding outlay or expenditure in another, and it is complete, meaning that the two parties in every transaction are identified (Sadoulet and de Janvry 1995). Through this simple approach, the SAM captures intersectoral linkages and calculates multipliers related to both production and consumption (discussed in Chapter 8). Applications of the SAM include examining income distribution effects of policies or economic shocks, and predicting how growth in one sector will affect another, etc. SAMs are usually built to represent entire country economies, but they can be done for a region within a country, or even a village. Subramanian and Sadoulet (1990), for example, constructed a village SAM to see how production fluctuations and technical change in an Indian village economy were transmitted to the rest of the village economy.

A SAM is constructed as a square matrix containing six types of economic accounts that transfer expenditure and income among each other. These accounts cover production activities, commodities used as inputs and consumption goods, factors such as labor and capital, institutions (households, firms and government) and their expenditures and incomes, capital (covering savings and investments), and the rest of the world (covering imports and exports outside the economy in question, regardless of its size).

It is easy to see that constructing a SAM requires very detailed, reliable data. This is especially so for disaggregated models powerful enough to trace detailed linkages and feedbacks. Very thorough survey work must underlie such data, otherwise the model risks yielding incorrect information. Subramanian and Sadoulet constructed their village SAM in one of the ICRISAT study villages where detailed data were available for 48 households over ten years. Even then, the authors had to collect a lot of additional data before they could construct the model.

Traditional SAM models are based on the assumption that production activities are endogenous and demand-driven. This assumes the existence of excess capacity throughout the economy. However, this assumption is not realistic for agriculture, in which production is constrained by available land, seasonal labor shortages and weather. Elasticity of supply is infinite in some models, so there is no price response to increasing demand for factors. Several authors, including Haggblade and Hazell and Subramanian and Sadoulet, adjusted their models to correct these shortcomings. Additional analytical methods are being developed rapidly, further reducing the need for strong assumptions in such models.

Multimarket Models

Multimarket models incorporate elasticities based on production and consumption functions (technical and economic relationships). This means that they can be used to relate the percentage change in a set of endogenous variables (such as prices and quantities) to a percentage change in a set of exogenous variables, given a set of underlying parameters (such as elasticities and shares). Analysts can use such models to simulate the effect of changes in economic policies or agricultural technologies on economic outcomes such as commodity supply and price or employment and wages. They can disaggregate consumers and producers into different categories (such as large farms, small farms and laborers, and poor and wealthy urban consumers), so they are useful for tracing the effects on income distribution.

The study by Renkow (1993) discussed in Chapter 7 used this approach to distinguish between the effects of technical change with and without government price controls. Studying the indirect effects of alternate approaches to food subsidies on efficiency, welfare and equity is another application. Sadoulet and de Janvry (1995) distinguish between highly rigorous models in which all model components are estimated econometrically, from more application-oriented approaches that use best-guess elasticities to trace through the effects across markets of price changes. The former is highly demanding and can take years to conduct, while the latter is relatively simple and helps guide intuition or check consistency. The classic example of the former is the study by Quizon and Binswanger referred to in Chapters 6 and 7, while the Renkow model is an example of the former.

Multi-market models' use of elasticities is an advantage over SAMS, but one limitation is that they focus only on one sector. Unlike economy-wide SAMs, they cannot estimate multipliers. Sadoulet and de Janvry provide a good summary of these models.

Computable General Equilibrium Models (CGEs)

Computable general equilibrium (CGE) models combine different aspects of the SAM and multimarket models. The structure is similar to an economy-wide SAM, but economic agents are price responsive as in the multimarket models, containing a variety of elasticities in production and consumption. Various macroeconomic relationships are also represented such as the balance of payments and government budget.

A CGE, like a SAM, is built to represent an existing economy. Once it is calibrated to reflect observed economic conditions and relationships, it can be used to test the effects of various policy scenarios. The analyst can introduce a price shock in one sector and then records how it affects other sectors under a new equilibrium.

These models are very powerful, but due to their large size and complexity it is only worth using them when the problem truly calls for it. Since they incorporate socioeconomic structure, intersectoral price relationships and macroeconomic effects, they are best used when all of these are important. In many cases, however, macroeconomic or intersectoral effects can safely be ignored and there is no need for a CGE (Sadoulet and de Janvry 1995). In this case a multi-market sectoral model is more appropriate.

13. CONCLUSIONS

More than thirty years after the green revolution, poverty still exists in the developing countries where it had its greatest impact. This does not mean that agricultural research has failed, however. Agricultural research and technology fit into a larger political, institutional and economic context and it would be naive to imagine that they could solve poverty problems on their own (Anderson et al. 1988b). At the same time, it is not likely that poverty alleviation can be achieved without them.

SUMMARY OF FINDINGS

Agricultural research has had many unconditionally positive effects, of which its effect in stimulating the supply of food is perhaps the most important. Increased agricultural production resulting from research-led technological change has propelled famine-plagued, food insecure Asian countries into food self-sufficiency. A large supply of food keeps food prices down, which is critically important to the poorest people who spend up to three-quarters of their income on food. Nutrition status has improved in many but not all countries.

Population growth has masked many of the gains provided by agricultural research. Food production has increased tremendously in developing countries, but food production per capita has grown only very slowly if at all. Also, agricultural productivity growth has created many jobs, but each year there are millions of additional unskilled workers who need jobs. The proportion of people who are poor has fallen significantly but, with population growth, the absolute number of poor people has not. It is difficult to eliminate poverty when most babies are born into households headed by parents who are very short on income, education or job skills.

Technological change has had ambiguous effects on income distribution across different categories of rural households. Cash-intensive technologies, for example, may be difficult for the poorest farmers to adopt. If other farmers widely adopt such a technology, higher aggregate output will result and output prices will fall. Nonadopting farmers will face lower returns under such conditions and they may become absolutely worse off as a result. A critical issue here is that effects of technical change on producers and workers are integrally linked to other institutions and policies. Technology is more likely to have widespread benefits if assets are equitably distributed and infrastructure and social services are well developed. Well-functioning, easily accessible markets for credit, for example, help farmers purchase productivity-enhancing inputs. Unfavorable social outcomes are more likely when these conditions are not in place.

Uneven adoption across regions is another source of concern about inequitable income distribution. Uneven adoption can lead to higher farm profits and wages in adopting regions but lower returns in less favorable, nonadopting regions. Evidence from Asia suggests that over time, some workers migrate from the nonadopting to the adopting areas where labor demand has risen and this reduces regional wage differences. Nonadopting regions shift to other crops in which they have a comparative advantage. Inequitable impact across regions is a reality, but there is a certain inevitability about this due to the importance of agroclimatic conditions in agricultural production.

It is important to note that while adoption of early green revolution varieties was confined to favorable irrigated areas and required major inputs of pesticides and fertilizer, subsequent research led to the development of modern varieties that perform well in unirrigated conditions and without chemical inputs. As a result, rainfed areas of India that adopted improved varieties in the 1980s exceeded the original irrigated area covered by the green revolution in the 1960s. Similarly, the latest improved wheat varieties do not require fungicides and the latest improved rice varieties do not require pesticide. Virtually all modern varieties respond to fertilizer, but they can also give respectable yields without fertilizer. Also, successive generations of improved wheat have become increasingly responsive to fertilizer, so that smaller applications have larger effects on yields. Performance will always be superior with better use of inputs, but recent technical improvements give cash-constrained farmers in rainfed areas better opportunities to raise their production greatly. In this sense agricultural technology has made steady progress in responding to the needs of poor people.

Evidence on changes in employment and wages resulting from technical change is complicated. Improved varieties raise employment, though this effect has weakened considerably since the initial introduction of green revolution varieties in the 1960s. Changes in real wages resulting from increased demand are difficult to track for at least three reasons. First, wages in the nonagricultural sector play a role in determining agricultural wages; second, economic policies influence wages; and third, steady growth in the population of unskilled job-seekers and migrants counteracts the demand effect. The agricultural sector has absorbed huge numbers of new workers since the 1960s, but raising their wages is difficult when labor supply has also grown by so much.

Agricultural productivity growth can stimulate wider growth in the nonfarm rural economy, which in turn can contribute to poverty alleviation. However, poverty alleviation through economic growth takes time and depends on favorable conditions such as relatively equitable initial division of assets, widespread access to infrastructure and government services, and promotion of labor-intensive enterprises. While economic growth is not sufficient to alleviate poverty, evidence suggests that it is necessary. Alongside economic growth, poverty alleviation requires special programs targeted to poor people to provide safety nets and give them opportunities.

LOOKING TO THE FUTURE

Agricultural research must continue to stimulate growth in yields of cereal crops. This is particularly important because it will help reduce the price and increase the availability of the basic grains that poor people depend upon. With growing urbanization and ever-smaller farm sizes, increasing numbers of poor families are net purchasers of food and so they will benefit from lower prices. Food prices do not depend solely on supply and demand; policy makers must also support efforts to keep food prices low.

On the production side, the poverty alleviation and income distribution implications of new agricultural technologies depend largely on economic, policy and institutional conditions in the areas where they are introduced. Accordingly, analysts rightly advocate policy reform to create more favorable conditions. However, policy reform typically is a slow and incomplete process, so agricultural researchers must not simply ignore income distribution issues or assign them to others. Rather, they should be aware of the socioeconomic environment in which they are working and avoid research on technologies likely to have negative income distribution implications under existing conditions.

It may also be possible to explicitly target agricultural research to address poverty alleviation objectives, but this may involve tradeoffs with efficiency that could slow economic growth. On the other hand, if successful approaches to using agricultural research for poverty alleviation were identified, they might prove to be cost-effective given the high cost and poor performance of many other anti-poverty measures. More research is needed to assess both the opportunities for targeting research to poverty alleviation and the tradeoffs with economic growth objectives.

Participatory research, in which poor people play a role in both setting the research agenda and carrying it out, has the potential to make agricultural research more effective and empower poor people by giving them more influence over the research system to address their needs, and by providing them with skills to solve their own problems. Participatory research should go hand-in-hand with participatory community development that can help improve access to credit and markets and can teach local people the skills they need to organize themselves, analyze and solve problems as a group, and resolve conflicts. Participatory research is a new field and new information about it is being generated rapidly. Early evidence suggests that it has strong potential for generating more productive and easily adoptable technologies, especially in areas with complex production systems. To date there is little documentation of its impact on poverty alleviation and this is an area worth investigating. A key issue here is that researchers must take steps to ensure that "participating" farmers represent all social groups, including the poorest and least influential.

Better management of soil, water and other crop inputs will be an important source of yield growth in the future. Ensuring that the poorest farmers benefit from improved crop management will depend on several factors. Areas with diverse farming systems, for example, may require more site-specific recommendations. Participatory research can help in this regard, and so will improved extension mechanisms. Farmers also require improved human capital in order to absorb increasingly complex management recommendations and to improve their own innovation skills. The examples of training farmers in IPM skills in Kenya and Honduras (Boxes 10.3 and 10.4) show the potential for high payoff to improved skills. Better education in general would also help improve farmers' analytical abilities.

Biotechnology has great potential to develop crop technologies with attributes favorable to poor people such as higher yields, higher nutrient content, and resistance to important pests, weeds and diseases. However, biotechnology is being developed mainly by developed country private sector companies that respond to the best market opportunities. As a result, they devote relatively little attention to priorities of poor people in developing countries. This contrasts with the green revolution technologies, which were developed through publicly-funded research that focused explicitly on poverty alleviation objectives. Harnessing biotechnology to address the needs of poor people will require creative institutional arrangements to transfer products and skills to developing countries. International organizations can play a role in this regard.

Research to assess the impact of agricultural research on poverty alleviation must overcome measurement difficulties associated with the fact that the relationship is indirect, with numerous confounding factors. Ideally the analyst would have data on conditions both before-and-after and with-and-without the introduction of new technology. This helps in ensuring that changes in poverty conditions are properly attributed to all of the actual determinants, including technology change but also other factors. There is also scope for introducing quasi-experimental design to control for confounding factors. This has long been used in nutrition studies but it is only just emerging in economic analysis.

Research to assess the impact of agricultural research on poverty alleviation can be particularly effective by combining quantitative and qualitative research methods. Quantitative approaches are needed to analyze complex, indirect relationships regarding poverty reduction, while qualitative approaches can help understand poverty from local people's point of view, capturing important relationships that outsiders might overlook.

KNOWLEDGE GAPS

This review of existing literature has found a great deal of information on the relationships between new agricultural technology and poverty alleviation, but important gaps remain. Most importantly, comparatively few studies reviewed even acknowledged the various confounding factors that can influence poverty outcomes, let alone control for them. Even when they did try to do so, there was little comparability across studies because they used different methods, asked different questions, and defined their problems differently. As a result, reviewing the literature involved piecing evidence together as well as possible, sometimes obtaining background information on confounding factors from separate sources. Despite the large volume of literature reviewed, room for debate remains on some important questions.

Answering some lingering questions will require a set of studies using common methodology, both quantitative and qualitative. This would help isolate causal relationships between new technology and poverty alleviations while also spelling out conditions under which they do or do not hold.

The problem of confounding factors is perhaps greatest regarding the distribution of income across different types of farms and between farm and labor income. This is also the topic on which there is the most literature arguing that new technology has negative distributional outcomes. A coordinated series of studies on these relationships would be particularly useful.

The food availability and price benefits of new agricultural technology appear to be unequivocal successes of agricultural research. Despite predictions in the 1960s of widespread starvation in subsequent decades due to the world’s inability to produce enough food, since the early 1970s this has not happened except in cases exacerbated by warfare and other social, economic and political turmoil. Lower food prices have also enabled millions of poor families to stretch their budgets further. On the other hand, some critics would argue that if lower food prices come at the cost of lower wages and lower incomes for poor farmers, then they merely serve to justify and maintain an unfair system that keeps poor people poor. There is a need for additional studies that examine both the production and consumption consequences of improved agricultural technology.

The studies by Quizon and Binswanger (1986), Renkow (1993), and Warr and Coxhead (1993) are examples of this approach.

One specific point on which there is little or no evidence is whether the approach to research (rather than just the products of research) affects poverty. For example, evidence is weak on the impact of participatory research, and what little information is available focuses on technology development and adoption, not poverty alleviation. One of the best examples of success to date may be the case of participatory bean breeding in Rwanda (Chapter 10), but literature on this experience does not focus on poverty alleviation.

Chapter 9 addresses the question of whether targeting agricultural research toward poverty alleviation objectives would be a good use of resources. The key question here concerns whether this approach would entail tradeoffs with productivity objectives. If so, any specific gains from targeting might be negated by reduced output and a possible decline in food availability or rise in food prices, harming the interests of poor consumers. Past efforts to shift research resources from productivity objectives to other aims, such as the effort to breed high-lysine maize described in Chapter 7, faced unacceptable productivity tradeoffs. However, other opportunities may exist without the same drawbacks and it is worth at least a small effort to examine their potential. Careful experimentation is needed to assess both costs and benefits of selectively targeting research away from purely productivity objectives. Most likely there exist at least some attractive opportunities, and that the potential for successful targeting and the extent of tradeoffs will vary by case. It is critically important to understand the conditions under which targeting is a useful objective.

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