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Modeling the Impact of Agricultural Growth and Government Policy on Income Distribution in India

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This article uses a limited general equilibrium model to investigate the growth and equity effects of a variety of economic and technical changes and selected agricultural policies in India. It explores how changes in food prices, rural wages, and farm profits associated with the Green Revolution period affected income distribution between net buyers and sellers of food. The model shows that income gains from the Green Revolution initially accrued to the wealthier rural groups but that after 1972–73 they were transferred to urban consumers and that by 1980–81 the per capita incomes of poor and wealthier rural groups alike were barely above their respective 1960–61 levels. The model is also used in counterfactual analysis of the impact of changes in technological, demographic, investment, taxation, and income redistribution variables. Its findings indicate the importance of trade policies for the nature of the equity outcomes from agricultural growth and suggest that a reduction in population growth and an increase in nonagricultural employment and income are required to convert agricultural growth into reduced rural poverty.

As a result of the Green Revolution, agricultural productivity in India has risen sharply over the last two decades and India has become a self-sufficient producer of basic food grains. While there is no dispute about the rapid increase in production, economists have not had available a similarly compelling analysis of who has benefited from this growth.

Debates about the effects of the Green Revolution and Indian agricultural policies on the distribution of income have, almost without exception, been limited to the question of how income is distributed across small and large farms and between landowners and workers, rather than between producers and consumers of food. Typical subjects of study have been the differences in adoption behavior of small and large farms, the distributional impact of their differential access to credit, and the direct labor-use effects of high-yielding varieties or of irrigation.

The determination of these direct first effects of changes in agricultural tech-

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niques and policies is, of course, necessary and important. Meanwhile, however, the longer-term macroeconomic effects of changes in agricultural technology and agriculture-related policies have not received sufficient attention. This paper presents a limited general equilibrium model which incorporates most of the relevant macroeconomic factors needed to determine the distributional impact of the Green Revolution. The model also allows assessments of other trends and policies that may be determinants of income distribution. This analysis is directed to the following objectives:

- To trace changes in income distribution between rural and urban groups and between different income groups
- To determine the equity effects of the Green Revolution
- To suggest how changes in economic, demographic, and technical trends would be likely to influence income distribution
- To indicate the effects of alternative government policies on equity and poverty.

In order to address these objectives, we developed a limited general equilibrium model that is capable of accounting for changes in rural and urban income induced by changes in agricultural commodity supply and demand. This model is described in section I of this paper and is presented in mathematical terms in appendix A. The major elements of the model are:

- The demand and supply of four agricultural outputs
- The demand and supply of three agricultural inputs
- Real incomes of rural and urban inhabitants at different income levels.

The key feature of the model is that prices and quantities of agricultural output and variable inputs are endogenous. The model differs from an economy-wide model, however, in that nonagricultural income and production are treated as exogenous.

Succeeding sections of the paper discuss several of the applications of the model.

Section II briefly describes a standard exercise which we carried out to compare the model's endogenous ex post predictions of the quantities and prices of agricultural inputs and outputs with the actual paths of such quantities and prices as shown by macroeconomic data. Section III discusses the use of selected equations from the model to account for changes in rural and urban income in India during the period from 1961 to 1981. In section IV, the model is used in counterfactual analysis to determine how income and agricultural variables would have changed under various hypothetical scenarios.

The model's findings are summarized in section V. Among other things, our investigations show that India's progress in agriculture during the twenty-year period in question apparently had little net positive effect on the incomes of either the rural well-to-do (the landowners) or the rural poor. The chief beneficiaries of increased agricultural output (which was accompanied by government policies that caused a relative decline in food prices as compared with manufactured goods prices) were urban residents. Our findings suggest that the incomes of the rural poor in India would be more likely to improve as a result of demographic changes and increases in nonagricultural employment than as a result of technological improvements in agriculture.

These conclusions, it should be understood, were arrived at through an ambitious attempt to try to understand an exceedingly complex reality. Our efforts to do so are subject to various limitations, many of which stem from a lack of complete data. In order to construct and utilize our model, many assumptions had to be made, and readers will find many caveats scattered throughout this article. The strength of the model, however, arises from our econometric estimation of parameter values which are based on the very large amounts of data compiled and incorporated into it. Despite its limitations, we hope that this paper can further the evolution of analysis of important issues in economic development.

I. A Summary of the Model

The limited general equilibrium model for our investigation determines quantities and prices in seven markets: three input markets, labor, draft power, and fertilizers; and four agricultural output markets, rice, wheat, coarse cereals, and other crops. It also determines residual farm profits. Given these prices and quantities, it then determines the real incomes of four rural and four urban income quartiles (R1, R2, R3, and R4 and U1, U2, U3, and U4, respectively, in the appendixes).

The supply of the four agricultural commodities and the demand for the three factors of production are modeled as a jointly estimated system of output supply and factor demand equations.[1] Output supply and factor demand shift in response to changes in exogenous endowment and technology variables: land (cultivable area), annual rainfall, irrigation, high-yielding varieties, roads, farm capital (animals and implements), regulated markets, and technological change.

The *supply of labor* is responsive to the real rural wage. Agricultural labor is supplied by rural groups and also by some urban emigration, which is responsive to the rural wage.

The *supply of draft power* is responsive to the real rental rate for draft animals and is supplied by each of the rural groups.

The *fertilizer supply* is treated as an aggregate of nutrient tons, which is responsive to the price of fertilizer relative to nonagricultural goods prices.

1. Separate systems were estimated for each of four agroclimate zones. These systems were then aggregated to the national level. A flexible functional form was used to allow for cross-price effects among all seven outputs and factors.

The *supply of land* is exogenously given as the cultivated area. This is appropriate, because area expansion in Indian agriculture has virtually stopped since the mid-1960s. However, this treatment still allows cropped area to vary endogenously via changes in the extent of double and triple cropping. And, of course, the area allocated to different crops can vary.[2] While the supply of land is exogenous, net returns to land (the residual farm profits after variable factors have been paid) are determined endogenously.

Consumer demand is responsive to the prices of commodities and the real income of each of the eight income groups. Poorer groups have higher income elasticities than richer groups. Each income group's demand must therefore be modeled separately. Demand was estimated econometrically; a flexible functional form was used, so that all (compensated) cross-price elasticities were directly estimated. Aggregate demand is the sum of the demands of all the income groups.

Nominal income is computed as each group's supply of agricultural production factors multiplied by the factor prices, plus an exogenously given component for nonagricultural income. *Real income* is calculated for each of the eight groups as their nominal income deflated by an endogenous consumer price index that is specific to that group's consumption patterns and reflects all endogenous changes in food prices.

Prices and quantities of commodities and factors of production are determined as those which equate aggregate supply and demand in each of the seven markets. The government can influence agricultural prices through the use of tariffs, food imports and exports, food grain storage, forced procurement at fixed prices, and consumer ration shop sales at nonequilibrium prices.[3] The model solves simultaneously for changes in endogenous prices and quantities and thus determines for each income group the change in its nominal income, price deflator, real income, labor supply, draft power supply, and level of consumption.

Nonagricultural prices are given exogenously and are used as the numeraire of the model. Because nonagricultural income is also given, nonagricultural production is exogenous and consumption of this output must adjust via trade.

The base year used in constructing the model is 1973–74. Initial values are computed largely from an extensive rural household survey by the National Council for Applied Economic Research.[4] The entire model is written in logarithmically linear equation form.

There are several important characteristics of the model which must be kept in mind while interpreting our findings.

First, it is well known that the distributional outcomes from general equilib-

2. Neither the total cropped area nor the area under different crops is explicitly traced in the model because the supply equations do not distinguish between area and yield supply.

3. Although we deal mainly with food trade in this paper, forced procurement and food subsidies are discussed in Binswanger and Quizón (1986).

4. For a fuller discussion of data sources and estimation of parameter values, see appendix B and Pal and Quizón (1983).

rium models depend crucially on labor market assumptions (Taylor 1979). We model the real rural wage by equating supply and demand for labor; that is, it is a full employment model. This treatment is consistent with the empirical evidence that there is little year-round unemployment in rural areas and that most unemployment is seasonal (Krishna 1976). Moreover, real wages are variable both within and across years; that is, no model of constant nominal or real wages is consistent with the data. Econometric studies of labor demand (Evenson and Binswanger 1984) and supply (Bardhan 1984; Rosenzweig 1984) are also consistent with our neoclassical treatment of the rural labor market.

In spite of this evidence in favor of a neoclassical approach, we are keenly aware that there is considerable friction in rural labor markets. For example, there are substantial and persistent interregional wage differentials, and seasonal unemployment is clearly present. But our model is not regional and does not deal with intrayear wage determination.

Similarly, because the model aggregates across different regions, it is not able to account for regional concentration of the Green Revolution. Because, in the longer term, increased production led to a decline in agricultural prices, farmers who had not adopted the Green Revolution technology—and whose yields had not increased—were harmed. Thus our simulation obscures both the more radical income gains in beneficiary areas and the declines in the nonadopting regions.

The model treats nonagricultural incomes (and implicitly urban wages and nonagricultural output) as exogenously determined. The purchasing power of the nonagricultural incomes, however, depends on agricultural prices. When these prices rise, urban agricultural demand will fall because of both price and income effects. But other feedbacks from agricultural activity to the nonagricultural sector are not allowed for in the model. One consequence of our treatment of the nonagricultural sector is that changes in food prices have no effect on the nominal urban wage; that is, reductions in food prices benefit urban wage earners and are not passed along to employers in the form of lower wages.

Although the model determines what happens to real farm profits and the incomes of the rural income groups, it does not treat endogenously what subsequently happens to private savings and private agricultural investments brought about by the changing fortunes of farmers. Thus our model is not a very long-run model. The reason for this treatment is that no econometric studies exist which quantify the link between farm profits and farm investment.

Because there is no adequate empirical evidence for the actual changes in factor or asset endowments, we have not attempted to track these changes in our analysis of income distribution trends and we do not have endogenous endowment changes in our simulations. For such an analysis, one would need either to get comprehensive and accurate data or to be able to model investment processes in land and other factors of production for each of the four rural income groups. At the present time, the absence of such empirical knowledge makes the modeling of endowment changes a distant goal.

Finally, the model leaves out the effects of the market for foreign exchange on agricultural performance, and vice versa. India is modeled as a state-trading economy in which decisions to export or to import agricultural commodities rest solely with the government. These decisions are exogenous to the model.

II. Comparing Model Predictions with Actual Changes

A set of experiments was performed to compare the model's predictions of agricultural prices and quantities with the actual prices and quantities reported. Ideally, one would want to compare the model's predictions of income distribution with actual patterns. Unfortunately, the data needed for such a comparison do not exist. Changes in exogenous variables (such as population, agricultural technology, capital and inputs, and nonagricultural prices and income) were introduced into the model for the five-year periods between 1960–61 and 1980–81, and the model's calculated production and prices were compared with the actual quantity and price data reported for those periods (see part B of appendix table 11). Difficulties encountered in compiling actual data for the comparison are discussed in appendix B.

In table 1, we compare indexes of actual and predicted values for six years and give the ratios of predicted to actual levels for each variable (with 1973 as the base). As can be seen, the fit between predicted and actual values is generally close despite the substantial changes that occurred in many actual values during the period. Of 65 predictions, 28 differ from the actual figure by 10 percent or more and only 10 by 20 percent or more. The poorest predictions are for the extreme years 1960–61 and 1980–81.

Although during the period as a whole we overpredicted the growth rate in agricultural output by only about 0.5 percent per year, our quantity predictions are better than our price predictions. On the price side, the most serious problem is the overprediction of the rate of growth in agricultural prices from 1975–76 to 1980–81. Figure 1 shows that actual terms of trade moved rapidly against agriculture during that period, but our model does not fully capture this downward trend, apparently because our model exaggerates the growth of demand. Notwithstanding these difficulties, the results show that our model is able to replicate reasonably actual agricultural conditions for the period.

Among the individual variables, fertilizer consumption in the pre–Green Revolution period is the one tracked least accurately. We overpredict fertilizer consumption in those early years by a factor of 200 percent. This error is partly due to an extremely low base-year value. We also underestimate the rapid growth in fertilizer demand in the 1975–76 to 1980–81 period. This may be partly because we are not able to account for the rapid growth in the fertilizer subsidy in our simulations.

Table 1. *Comparative Indexes of Production, Employment, Wages, and Prices*

Variable	Agricultural year				
	1960–61	1965–66	1970–71	1975–76	1980–81
All crop production					
Actual value	78.46	79.95	101.02	108.23	122.16
Predicted value	74.83	78.28	98.62	108.49	130.28
Ratio of predicted to actual value	0.95	0.98	0.98	1.00	1.07
Rice production					
Actual value	82.82	81.49	101.91	106.01	121.37
Predicted value	82.65	83.81	100.05	107.68	125.95
Ratio of predicted to actual value	1.00	1.03	0.98	1.02	1.04
Wheat production					
Actual value	47.32	48.24	99.69	116.10	149.54
Predicted value	41.39	52.83	95.59	117.51	162.49
Ratio of predicted to actual value	0.87	1.10	0.96	1.01	1.09
Coarse cereal production					
Actual value	89.19	90.96	106.45	108.52	110.81
Predicted value	82.12	80.96	99.35	108.52	119.59
Ratio of predicted to actual value	0.92	0.89	0.93	1.00	1.08
Other crop production					
Actual value	83.05	86.86	99.07	107.05	116.10
Predicted value	75.57	80.79	97.62	105.26	127.27
Ratio of predicted to actual value	0.91	0.93	0.99	0.98	1.10
Fertilizer consumption					
Actual value	11.45	32.50	84.30	108.53	205.85
Predicted value	35.21	58.75	74.44	114.46	182.02
Ratio of predicted to actual value	3.08	1.81	0.88	1.05	0.88
Employment					
Actual value	85.17	90.62	96.07	102.62	109.17
Predicted value	81.54	86.60	95.49	103.36	111.74
Ratio of predicted to actual value	0.96	0.96	0.99	1.01	1.02
Rice prices					
Actual value	92.89	93.68	97.15	101.78	89.97
Predicted value	92.98	116.50	81.19	107.88	120.87
Ratio of predicted to actual value	1.00	1.24	0.84	1.06	1.34
Wheat prices					
Actual value	100.57	109.06	108.30	106.36	85.35
Predicted value	120.20	134.52	86.33	108.54	103.66
Ratio of predicted to actual value	1.20	1.23	0.80	1.02	1.21
Coarse cereal prices					
Actual value	93.13	106.49	86.09	90.70	74.70
Predicted value	102.38	116.84	85.77	95.20	101.38
Ratio of predicted to actual value	1.10	1.10	1.00	1.05	1.36
Other crop prices					
Actual value	100.74	99.20	103.56	95.59	101.66
Predicted value	93.22	114.29	87.44	105.41	126.31
Ratio of predicted to actual value	0.93	1.15	0.84	1.10	1.24
Labor wages					
Actual value	102.57	104.85	109.57	97.69	98.40
Predicted value	116.22	121.74	93.05	102.00	105.57
Ratio of predicted to actual value	1.13	1.16	0.85	1.04	1.07
Prices of all commodities					
Actual value	100.00	100.00	100.00	100.00	100.00
Predicted value	100.11	113.49	88.80	105.30	119.08
Ratio of predicted to actual value	1.00	1.13	0.89	1.05	1.19

Source: World Bank data; see appendix table 11.

Figure 1. *Agricultural/Nonagricultural Terms of Trade for India, 1960–61 to 1980–81 (Actual Data; 1973–74 = 100)*

Source: Appendix table 11, part A.

III. Accounting for Changes in Income Distribution

In this section we compute a reference path of the real incomes of each of the rural and urban income groups during the period from 1960–61 to 1980–81. We generate the implied distribution of income among the eight groups by using actual estimates of agricultural output, agricultural prices, wages, and fertilizer consumption, as well as the exogenous variables that affect the income and factor market equations in the model. The numbers in table 2 are indexes of the predicted levels and are calibrated so that the predicted level of each variable is equal to 100 for 1970–71, the end of the first phase of the Green Revolution.

We assumed that during the twenty-year period, the across-quartile shares in ownership of factor inputs and within-quartile shares of nonagricultural and factor incomes in total income remained equal to their respective base-year (1973–74) values (see discussion in section I). We also assumed that the rates of growth in the population, in the agricultural capital stock, and in the nonagricultural income of each quartile were the same across the groups. But there may have been other causes of change in actual incomes that we were unable to account for, such as changes in taxation, in investment behavior, in people's occupations, and in food subsidies. Table 2 shows what would have happened to real income as a result of changes in agricultural production and technology, agricultural output and input prices, nonagricultural incomes and prices, and population. Although the total endowments of the various groups change over

Table 2. *Simulated Indexes of Income Distribution and Income Sources, India, 1960–61 to 1980–81*
(1970–71 = 100)

	Agricultural year					
Endogenous variables	*1960–61*	*1965–66*	*1970–71*	*1973–74*	*1975–76*	*1980–81*
Real per capita income (actual)						
National	92.0	95.0	100	95.1	95.4	105.9
Rural, by quartile						
First (poorest)	101.0	99.0	100	95.9	97.4	107.0
Second	96.9	95.8	100	94.6	94.8	99.9
Third	93.8	93.5	100	93.8	93.3	96.3
Fourth (richest)	88.5	88.6	100	92.4	90.7	88.8
Aggregate[a]	92.9	92.4	100	93.6	92.9	94.9
Urban, by quartile						
First (poorest)	91.9	100.4	100	98.1	100.7	136.0
Second	90.9	102.8	100	99.3	102.6	141.9
Third	90.2	102.7	100	99.7	102.5	139.3
Fourth (richest)	87.6	102.3	100	99.8	102.2	133.5
Aggregate[a]	89.4	102.3	100	99.4	102.2	136.7
Agricultural employment	98.2	100.1	100	112.3	118.8	118.5
Real agricultural wage bill	91.2	95.3	100	101.4	104.9	105.4
Real residual farm profits	64.2	67.9	100	86.0	85.1	76.4
Nonagricultural income	71.9	93.6	100	111.3	121.8	182.7
Real per capita disposable income	92.4	94.5	100	96.7	97.8	113.6
Total actual agricultural output	79.3	81.2	100	99.4	107.1	119.6
Actual prices = agricultural/nonagricultural goods	89.8	97.2	100	97.7	91.6	76.3

a. These estimates of per capita income are computed as in equation 16 of appendix A, in which the subscript k now refers to either the rural quartiles (R1 to R4) or the urban quartiles (U1 to U4) only.

time, the relative endowment position of each group was assumed to remain the same.

The last two rows of table 2 show the actual growth of total agricultural output and the change in agricultural terms of trade. Agricultural production grew rapidly during the early Green Revolution period (1965–66 to 1970–71) and again from 1973–74 onward, while agricultural terms of trade rose prior to the Green Revolution, stayed fairly constant until 1973–74, and then dropped substantially by 1980–81.

These changes in quantity and price explain the changes in farm profits. Farm profits were seriously depressed in 1960–61 and in 1965–66 but then moved dramatically upward by 1970–71. By 1973–74 they had declined to 85 percent of their 1970–71 level, and by 1980–81 to 76 percent of the 1970–71 level. In these years, declines in output prices outweighed rapid growth in agricultural output.

Employment in agriculture (estimated in our model) grew by about 20 percent during the twenty-year period. Because real wages declined by about 5 percent, the total real wage bill for the period rose by about 15 percent.

Nonagricultural real income more than doubled during the period, with the most rapid increases occurring just prior to the Green Revolution and between 1975–76 and 1980–81. This latter gain occurred partly because the numeraire by which nonagricultural income is deflated gives a large weight to agricultural commodities, the prices of which had declined.

The trends in output and factor prices, and in agricultural and nonagricultural income, suggest that real aggregate per capita income among rural people grew by only about 8 percent during the early Green Revolution, after which it declined and stagnated. Despite a drastic shift in the distribution of rural income from wages to profits in the early period, rural income distribution was remarkably stable for the period as a whole. The effect of adverse wage trends on the rural poor was partially alleviated because agricultural employment increased somewhat and because the poor participated to a small extent in the growth of farm profits. About 11 percent of their income was derived from such profits. They also had substantial gains in nonagricultural incomes,[5] and as consumers they benefited from the decline in agricultural prices during the last five years of the twenty-year period.

The first period of the Green Revolution was one of substantial gains in farm profits. But the rapid gains in production during the late 1970s did not translate into further advances in income because the prices of agricultural products fell. The production gains from the early Green Revolution period were associated with rising prices because the government used the gains largely to replace imports. But once self-sufficiency in food grain production was more or less assured, the surplus grain production had to be absorbed domestically. This was a classic example of the process in which productivity gains in agriculture were transmitted to consumers (both rural and urban) by way of declining prices.

It is therefore not surprising to find that urban groups showed the largest gains in income, although their gains were largely a phenomenon of the last five years of the twenty-year period. They appear to have gained during the first quinquennium as well, but that gain was made despite rises in agricultural prices. In the late 1970s the combination of rapid nonagricultural growth and declining agricultural terms of trade greatly benefited the urban groups, with the biggest beneficiaries being the urban poor, since they spend a larger share of their incomes on food.

IV. Simulations of Alternative Policies and Trends

The previous section offers only partial explanations of why wages, farm profits, and income distribution evolved the way they did. An assessment of how

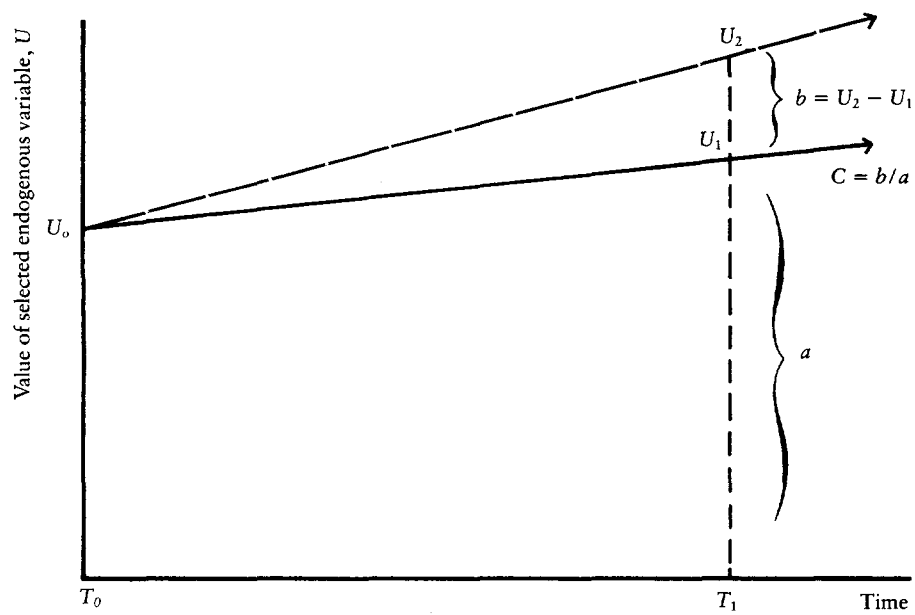
5. Nonagricultural sources provided 21 to 26 percent of the nominal per capita incomes of rural groups.

each individual change in a policy or a trend affects the model's outcomes is required to separate out the influence of different factors.

We do that in this section by comparing the results of a simulated change in selected trends or policies with the "base case," which reflects what actually occurred in India during this period. Thus we simulate a change in a specific exogenous demographic variable, for instance, and trace the effect of the change on production, prices, employment, and farm profits and through them see how income distribution would have been affected. Figure 2 illustrates this process. U_0U_1 is the path of the specific endogenous variable given actual policy trends and events, and a is the value of U at U_1. The variable U could be any of the twenty-eight shown in the left-hand column of tables 3 through 6. U_0U_2 is the simulation path of U if an exogenous change or intervention occurred, such as any of those shown in the column headings of tables 3 through 6. The value b is the difference between U_2 and U_1, the induced change in U at T_1; and C is the percentage change in U, or b/a. These percentage changes are the values reported in tables 3 through 6. In table 3, T_0 to T_1 is a ten-year period, while in tables 4, 5, and 6, T_1 is perhaps three to five years, sufficient time for farmers to respond to changes in technology, policies, and prices by adjusting their production patterns.

In order to explicitly track the changes in the terms of trade between agricul-

Figure 2. *Simulated Changes in Trends and Policies: Derivation of Values, Tables 3 through 6*



Note: C = percentage change in simulated value of U from its "base" trend value, as the result of a simulated change in one or more exogenous variables. C values are those shown in tables 3 through 6.

ture and nonagriculture, we use nonagriculture commodities as the numeraire. The change in the gross national product (GNP) deflator shown below is therefore a direct function of the change in terms of trade, not of inflation.

Demographic and Urban Growth Scenarios

In demographic scenarios 1.1a and 1.1b (see table 3), the assumption is made that population growth in India (both rural and urban) is reduced by 10 percent during a decade. Total nominal nonagricultural income is reduced by 10 percent as well and is therefore unaffected on a per capita basis. In scenario 1.1a the labor force continues to grow at the same rate as before—that is, this scenario is a stylized representation of a reduction in fertility alone, which would not affect the size of the labor force. In scenario 1.1b we assume that the reduction in fertility has caused a (long-run) decline in labor force growth and shows, in a stylized way, the effects of these reductions in fertility and labor force growth during a ten-year period.

In the first row of table 3 we see that the postulated fertility decline leads to a substantial gain in national income of about 5.6 percent and 5.2 percent in the two cases. In the second row we see that output declines somewhat more sharply (−1.2 percent) when labor force growth is also reduced than it does initially when the labor force still continues to grow (−0.6 percent). Aggregate prices, reflected in the GNP deflator, decline sharply (−19.4 percent and −18.1 percent respectively). The main difference between the two scenarios is in wages. Real wages decline by about 3 percent during the first decade because of reduced demand for agricultural output, whereas they increase by about 10 percent in our (stylized) long term. This is because long-run agricultural labor employment declines by about 5.5 percent in the latter case, so wages must rise.

In scenarios 1.1a and 1.1b there is a progressive impact on rural and urban income. The rich rural group (landowners) loses only a little in real income in the first decade (−3 percent), but in the long run this group loses more (−7.4 percent) as its members must begin to pay higher real wages. The increase in wages, coupled with declining demand, leads to a sharp reduction of 45 percent in residual farm profits. Under both scenarios, the poor in both rural and urban areas gain from the substantial decline in food prices. They gain a little more so in the long run because they also benefit from increased scarcity of labor (+15.5 percent and +19.7 percent for the rural and urban poor, respectively). The urban group gains the most since it benefits not only from lower food prices but also encounters less erosion of income as rural-to-urban migration is reduced.

Nutrition, measured here as cereal consumption, improved in all groups except in the rich urban and rural groups. For the lowest income groups the improvement is somewhat smaller than the change in real income, whereas for the richest groups the change in nutrition is much smaller than the change in income. This reflects the fact that richer groups have lower income elasticities.

Simulated scenario 1.2 in table 3 is one of urbanization. Rural population is assumed to decline by 10 percent, while urban population increases by 40.2 percent, enough to absorb the rural population. (Nominal urban income is increased by 40.2 percent in order to hold nominal per capita income constant.) In the absence of a continued rural-urban income differential, no migration would occur and the scenario would be unrealistic.

The main feature of scenario 1.2 is the assumed reduction in the number of agricultural producers while the number of consumers remains constant. Therefore, agricultural terms of trade rise sharply, which drives the GNP deflator up by 32 percent.

The reduction in agricultural population leads to a real wage increase of 9.4 percent, while the sharp increase in agricultural prices allows residual farm profits to rise by 58 percent. These effects drive the income distribution effects. Large farmers gain by nearly 30 percent, while the rural poor benefit both from increased wage income and increased farm profits, which account for 11.32 percent of their real income (appendix table 8). These gains more than offset their losses as consumers, and their incomes rise by a modest 3 percent. For the urban poor, however, the outcome is a fall of 21 percent in income as food prices rise. The losses of the second urban quartile are somewhat higher than the losses of the first (poorest) quartile. This occurs because the poorest urban quartile supplies some labor to the agricultural sector, whereas the second quartile does not. The urban rich lose less (−15 percent) than other urban groups because they spend a smaller part of their income on food.

Simulated scenario 1.3 combines scenarios 1.1b and 1.2. Overall population and labor force growth rates both decline by 10 percent, but the decline is accompanied by a rural-to-urban migration. The net effects are a decrease of 20 percent in the rural population and an increase of 30.2 percent in the urban population. The result is a large gain (14.3 percent) in real national per capita income. Meanwhile, agricultural prices increase, which leads to a modest increase in residual farm profits (13 percent). Therefore, all rural income groups experience real income gains of about 20 percent. Urban groups, however, lose.

We should note here that this scenario would not last indefinitely. People would not continue to move to urban areas in the face of a substantial decline in real wage incomes. Nominal incomes must rise if urbanization is to continue. We investigate the effect of such a rise alone in scenario 2.1 and then combine it with the demographic cum urbanization scenarios in scenario 2.2.

Scenario 2.1 lets the exogenous component of urban income increase by about 19 percent. Aggregate agricultural output increases only slightly (0.7 percent) in response to the increased demand for food because output is quite inelastic. Instead, the increased demand for food resulting from the rise in urban income translates into a substantial increase in the aggregate price level of food (16.6 percent). Thus, much of the increase in urban consumption of food must come from reduced consumption among the poorer two rural groups.

Table 3. *Simulated Effects of Demographic Changes*
(percentage change)

	Scenarios for changes in exogenous variables					
	Reduced population growth		*Urbanization*			
	Labor force growth rate		*Population and labor growth*			
Endogenous variables	*Steady (s1.1a)*	*Reduced (s1.1b)*	*Steady (s1.2)*	*Reduced (s1.3)*	*Rise in urban income (s2.1)*	*Combined scenarios: 1.1b + 1.2 + 2.1 (s2.2)*
National income per capita	5.63	5.20	9.08	14.29	6.49	20.78
Output						
Total	−0.64	−1.23	0.91	−0.32	0.74	0.42
Rice	−0.39	−1.97	2.32	0.35	1.25	1.60
Wheat	−4.58	−5.70	10.95	5.25	5.66	10.92
Coarse cereals	−2.43	−3.37	−17.12	−20.48	−5.61	−26.10
Other crops	0.44	0.56	2.04	2.60	0.84	3.43
GNP deflator	−19.44	−18.12	31.76	13.64	16.64	30.28
Prices						
Rice	−27.40	−25.51	45.02	19.51	23.04	42.55
Wheat	−34.83	−32.68	58.14	25.47	30.09	55.56
Coarse cereals	−32.83	−25.81	28.38	2.57	16.58	19.14
Other crops	−21.41	−21.00	40.12	19.12	21.08	40.20
Wage rate	−2.88	10.14	9.42	19.56	−0.35	19.22
Employment	−0.71	−5.46	−5.92	−11.38	−0.47	−11.85
Wage Bill	−3.59	4.68	3.50	8.18	−0.82	7.37
Profits	−36.01	−45.37	58.46	13.09	35.14	48.23

Income per capita (by quartile)						
Rural						
Poorest	14.91	15.53	3.13	18.56	−3.89	14.67
Second	8.61	7.72	11.62	19.33	1.51	20.84
Third	4.64	2.46	17.31	19.77	5.13	24.90
Richest	−3.34	−7.44	29.86	22.43	12.59	35.02
Urban						
Poorest	14.99	19.67	−20.95	−1.28	4.10	2.82
Second	16.55	21.02	−26.86	−5.84	2.73	−3.11
Third	14.22	19.02	−23.29	−4.27	4.47	0.20
Richest	8.44	13.62	−14.67	−1.05	9.12	8.07
Per capita cereal consumption						
Rural						
Poorest quartile	13.78	12.61	1.24	13.85	−2.95	10.91
Richest quartile	−0.54	−2.24	10.34	8.09	4.60	12.70
Urban						
Poorest quartile	14.64	16.93	−17.04	−0.11	1.96	1.85
Richest quartile	−0.58	0.55	3.15	3.70	6.54	10.25
Aggregate per capita cereal consumption	8.03	6.80	0.53	7.33	0.95	8.28

Note: The values shown are the percentage changes in the endogenous variables from their base case level, as the result of the induced change in the exogenous variables shown in the column headings.

All income, output, price, wage, profit, and consumption variables are real values.

The income groups shown are expenditure quartiles for rural and urban populations separately. The four rural expenditure quartiles together constitute 0.8009 of the total population, while the four urban quartiles include 0.1991 of the total population.

Since agricultural output rises only slightly, real wages are largely unaffected, but residual farm profits rise by 35 percent because of higher food prices. The rural poor lose 3.9 percent of their real income, but large farmers gain by more than 12 percent. Since urban groups must share their initial income gain of 19 percent with large farmers, the urban gain is reduced to about 9 percent for the urban rich and only 3 percent to 4 percent for the urban poor.

Scenario 2.2 groups the combined effects of the slowdown in population growth and labor force growth (1.1b), faster urbanization (1.2), and urban income growth (2.1). The effects on the endogenous variables are largely additive. Real urban incomes stay about constant, except for those of the urban rich, which rise by 8 percent. The incomes of the rural poor rise by about 14.7 percent, while those of the rural rich increase 35 percent. As long as the reduction in the number of agricultural producers and the rise in nominal urban income are not accommodated by more imports, the rural groups are the main beneficiaries. It is important, however, to realize that if increases in food prices were precluded by additional imports, the distributional outcome would be more favorable to the urban groups and less favorable to the rural rich.

Technical Change Scenarios

In simulated scenarios 4.1 and 4.4 (see table 4), yields of each individual crop or crop group are assumed to rise by 20 percent, a change corresponding to a major varietal shift like the Green Revolution. In scenario 4.5, the yield gain is smaller (10 percent) but is distributed evenly across all crops.

We present two versions of each of these scenarios. In the first versions (scenarios 4.1a, 4.2a, 4.3a, and 4.4a), the economy is considered closed and additional production is consumed in India. But in the second versions (scenarios 4.1b, 4.2b, 4.3b, and 4.4b), the extra yield is either exported or used to reduce imports of the commodity in question. The exported quantities (or the reduction in imports) were considered to be base-year domestic production multiplied by 20 percent. It is only after this initial increased quantity of output is exported that our simulation allows for farmer adjustment of crop mix into the more profitable crops as yields and prices change.[6]

Note that the b scenarios correspond to an assumption of state trading; it is not an open economy model with trade in many commodities. The exports (or reduced imports) of the b scenarios are an extreme assumption which the government is unlikely to carry out. It would probably alter exports (or imports) by a magnitude ranging from full domestic absorption of the surplus, as in the a scenarios, to full export of the increase in the b scenarios. Any desired intermediate point can be obtained by computing the appropriate linear combination of the impacts of the a and b scenarios.

When an increase of 20 percent in rice yields has to be absorbed domestically,

6. For a detailed discussion of how technical change is introduced in the model, see appendix III of Quizón and Binswanger (1984).

the result is a sharp decline in the price of rice (−31 percent) and in the price of its closest substitute, wheat (−15 percent). Rice production increases by about 20 percent, while wheat production declines by about 6 percent. Prices of the other agricultural commodities also decline by about 6 to 8 percent. The GNP deflator therefore declines by about 12 percent, while total agricultural output increases by about 5 percent. The price decline and the increase in agricultural output imply a real national income gain of about 4 percent.

The increased agricultural output requires only moderately larger labor inputs (1.1 percent), and the increased demand for labor results in modestly higher (1.5 percent) real agricultural wages.

The declines in agricultural prices, combined with the rise in wages, lead to a reduction in residual farm profits despite the increase in agricultural productivity. The price, farm profit, and wage effects largely explain the distributional outcome. Net buyers of food gain, and the more so the larger is their share of income spent on food. The urban poor gain the most (12 percent and 13.6 percent). The rural poor also benefit, since they too spend most of their income on food. Moreover, they benefit from the slight rise in wage levels. Since reduction in farm profits affects them only slightly, they end up with a net gain in real income of 7.5 percent. The rural rich, however, derive much income from farm profits, and their gain as consumers is not sufficient to offset their loss in profits. Their real income therefore falls by 1.4 percent.

A decision to export all the initial increase in rice production would sharply alter the distributional outcome. Since national income would rise by 5.7 percent, domestic demand would increase, which would lead to a rise of 10 percent in the domestic price level. Meanwhile, aggregate agricultural output would also rise because of the additional incentive to export. Rice production alone increases by 28 percent, which is 8 percent more than the increase caused by the technical change. Increased profitability, in other words, leads to extra resources being allocated to rice.

In this scenario, employment and real wages increase modestly. But price increases, combined with improved efficiency in production, lead to a rise in residual farm profits of 36 percent. These price, wage, and profit changes combine to produce a regressive distributional impact. All urban consumer groups lose, with the poor being hardest hit, and cereal consumption declines.[7] Meanwhile, the losses of the rural poor on the consumption side reduce their income gain to a mere 1.3 percent, while the rural rich experience a major gain in income of 14.8 percent.

The sharp effects of trade on income distribution are also evident in the other technical change scenarios, although magnitudes and other details differ significantly by commodity. Except in the case of coarse cereals, the gains of the urban groups are larger than those of any rural group when the extra output caused by

7. The losses of the poorest urban group are slightly less than those of the second quartile because of the greater direct participation of the poorest in the agricultural labor market.

Table 4. *Simulated Effects of Technical Change and Increased Exports*
(percentage change)

	Scenarios for changes in exogenous variables									
	20 percent increase in yield								*10 percent increase in all crop yields*	
	Rice		*Wheat*		*Coarse cereal*		*Other crops*			
Endogenous variables	*Closed (s4.1a)*	*Exports (s4.1b)*	*Closed (s4.2a)*	*Exports (s4.2b)*	*Closed (s4.3a)*	*Exports (s4.3b)*	*Closed (s4.4a)*	*Exports (s4.4b)*	*Closed (s4.5a)*	*Exports (s4.5b)*
National income per capita	4.10	5.65	1.98	0.02	1.01	2.08	7.31	10.58	7.20	10.20
Output										
Total	5.35	6.19	2.11	2.13	2.26	2.48	10.34	12.18	10.03	11.49
Rice	20.09	27.90	−1.67	−1.35	2.82	0.51	−0.55	0.64	10.35	13.85
Wheat	−5.94	1.78	18.33	29.27	1.46	1.82	1.14	9.35	7.49	21.11
Coarse cereals	4.86	−5.42	1.49	−3.57	12.75	22.21	−4.55	−14.02	7.28	−0.40
Other crops	0.16	−1.62	0.81	−0.49	−0.16	−0.69	21.20	24.52	11.00	10.86
GNP deflator	−11.96	10.13	−6.59	6.14	−4.91	5.59	−12.78	22.24	−18.13	22.05
Prices										
Rice	−30.87	9.10	−8.86	9.60	−1.81	10.85	−10.36	35.29	−25.95	32.42
Wheat	−21.13	19.62	−29.26	8.04	−4.05	13.55	−8.04	47.72	−31.24	44.46
Coarse cereals	−6.74	13.92	−6.07	7.24	−35.50	−6.24	−17.89	18.84	−33.10	16.88
Other crops	−8.12	14.45	−3.47	7.79	−3.73	6.89	−23.78	24.05	−19.55	26.59
Wage rate	1.54	2.39	0.14	0.82	−2.08	2.10	0.21	−0.87	−0.10	2.22
Employment	1.14	0.81	0.23	0.17	−0.37	0.83	0.18	−0.88	0.59	0.46
Wage bill	2.68	3.20	0.37	0.99	−2.45	2.93	0.39	−1.75	0.50	2.69
Profits	−7.54	36.07	−4.11	17.63	−1.08	15.03	4.11	80.75	−4.31	74.74

Income per capita (by quartile)										
Rural										
Poorest	7.52	1.33	2.65	−0.62	3.98	1.48	5.74	−2.05	9.95	0.07
Second	5.06	6.06	1.89	2.02	1.84	2.69	5.72	9.64	7.26	10.20
Third	3.55	9.22	1.23	3.71	0.75	3.54	5.82	17.56	5.67	17.02
Richest	−1.37	14.85	−0.04	7.21	−0.12	6.15	5.20	32.86	1.84	30.53
Urban										
Poorest	12.02	−6.90	7.47	−4.45	3.28	−3.92	12.79	−18.02	17.78	−16.65
Second	13.61	−7.69	6.15	−5.43	1.78	−5.22	13.47	−20.66	17.51	−19.50
Third	11.09	−7.07	5.46	−4.69	1.24	−4.53	12.60	−18.12	15.19	−17.20
Richest	5.74	−4.77	2.79	−2.91	0.09	−2.63	11.04	−10.69	9.83	−10.50
Per capita cereal consumption										
Rural										
Poorest quartile	11.21	2.03	2.62	−1.27	7.83	2.06	0.63	−3.88	11.14	−0.53
Richest quartile	4.27	6.46	3.03	2.59	−0.68	1.20	−4.27	8.24	1.18	9.25
Urban										
Poorest quartile	13.07	−5.01	9.48	−3.49	5.63	−2.78	5.27	−16.96	16.72	−14.12
Richest quartile	6.75	3.50	0.81	0.20	−1.36	−0.35	−5.43	−0.81	0.39	1.27
Aggregate per capita cereal consumption	10.14	3.70	3.57	.00	4.16	1.02	−0.93	−0.12	8.47	2.29

Note: The values shown are the percentage changes in the endogenous variables from their base case level, as the result of the induced change in the exogenous variables shown in the column headings.

All income, output, price, wage, profit, and consumption variables are real values.

The income groups shown are expenditure quartiles for rural and urban populations separately. The four rural expenditure quartiles together constitute 0.8009 of the total population, while the four urban quartiles include 0.1991 of the total population.

technical change is absorbed domestically. (In the case of coarse cereals, the gains of the rural poor exceed those of the urban group because urban consumers buy very little coarse cereals.) It is clear that the export of the initial gain caused by the technical change always leads to losses for urban consumers and is associated with a sharply regressive distribution of its benefits in rural areas.

Differences in the magnitude of the effects associated with technical change are partly a reflection of each commodity classification's share of agricultural output. Rice and other commodities have the largest shares, 26.7 percent and 51.3 percent respectively (see appendix table 9). Technical changes that affect the production of these commodities therefore contribute more to national income. The shares of coarse cereals and wheat are roughly 10.7 percent and 11.3 percent respectively, so their national income contributions are more modest.

However, final demand elasticities matter as well. Other commodities have the highest income elasticity (see appendix table 4). In the no-trade scenario, therefore, the decline in the own price of other commodities (−23.8 percent) is smaller than the decline in the own price of any other crop following an equal technical change. Coarse cereals are at the other extreme. A 20 percent increase in yield leads to a 35.5 percent decline in prices.

The income distribution impacts of the trade and no-trade scenarios differ accordingly. Technical change that affects other commodities benefits urban groups fairly evenly, and the disparities among rural groups are also modest. But technical change that affects coarse cereals clearly benefits the poor urban and poor rural groups, while neither the urban nor the rural rich gain.

As the all-crop scenarios (4.5a and b) illustrate, trade policy is the major determinant of the distributional outcome of technical change. The gains for the urban poor can vary from a high of 17.8 without trade to a low of −16.6 percent in the open economy scenario, depending on how much of the gain in yield is exported or used to reduce imports. For the rural rich, gains can vary from 1.8 percent to 30.5 percent while the impact on the urban rich can range from a gain of 9.8 percent to a loss of 10.5 percent.

When technical change affects all crops positively and there is no expansion of trade, the poorest rural group gains 9 percent from drops in prices but virtually nothing from wage rises. When, however, the full gains from technical change are exported, the poorest rural group sees no fall in prices. But its wages rise, and to a small extent this group also benefits from the massive rise in farm profits. On balance, both of the poorest rural quartiles would still be much better off without an increase in trade. The situation is reversed for the second income quartile. The positive farm profit effects outweigh the negative food price effects. When exports increase as a consequence of technical change, the income gain of the second rural quartile is 10.2 percent; without exports the gain drops to 7.3 percent.

A remarkable feature of technical change scenarios is the modest impact they have on real rural wages, regardless of what happens in trade. The largest absolute change in the real wage bill is an increase of 3.2 percent in scenario

4.1b. This very small wage response is not caused by the elasticity of labor supply, which is instead very inelastic. The total supply elasticity of rural labor, including the migration response, is less than 0.5. Demand for labor is also inelastic (−0.48) and thus cannot account for the limited wage response. Indeed, when labor is withdrawn from rural areas, either because of reduced fertility (scenario 1.1b) or rural-to-urban migration (scenario 1.2), real rural wages increase sharply.

Real wages remain stable despite technical change because technical change has contradictory effects on the demand for labor. As yields increase, less labor is needed to produce any given level of output, and thus labor demand is depressed. At the same time, however, the technical change has increased real incomes and reduced the relative prices of agricultural commodities, so that demand for the products increases. Thus, while the *per unit* labor requirement has declined, the impact on total labor demand is offset by the induced *rise* in demand for and production of agricultural commodities. It is the balance between these offsetting forces which determines the final effect on the demand for labor.

The findings shown in tables 3 and 4 should dispel the notion that technical change is responsible for the slight wage decline observed in section II. This decline must instead be the result of inadequate growth in labor demand in the nonagricultural sector.

Investment Scenarios and Fertilizer Subsidies

In this subsection we present only closed economy scenarios.

Under scenario 5.1 (see table 5), the assumption is that investment in irrigation is accelerated enough to increase the percentage of area irrigated by 10 percent. This leads to an increase in aggregate output of 2.7 percent and a drop in the aggregate price level of 5.8 percent. Because irrigation requires labor, labor employment and real wages rise slightly. Residual farm profits, however, decline by 4.8 percent as a consequence of slightly higher labor costs and lower output prices. The income distributional outcomes follow from these price and profit changes. The landless gain modestly (2.9 percent), while large farmers lose (−0.7 percent). All urban households gain substantially, with the poorest showing the largest gain (6 percent).

In the aggregate, real per capita income rises modestly (1.7 percent). Changes in the yield and price of individual commodities thus reflect shifts in income distribution rather than aggregate income growth. Wheat shows the biggest production increase and the largest price drop.

Scenario 5.2 focuses on expanding such capital inputs as tractors, other implements or machines, and livestock, and on improving the marketing infrastructure. Both of these are accelerated by 10 percent. Real per capita income then decreases slightly (0.2 percent) as a consequence of producer losses. Aggregate agricultural output increases by about 0.8 percent, and the price index drops by 3 percent. The effects on income distribution are similar to those of increased

Table 5. *Simulated effects of increased agricultural investment and inputs*
(percentage change)

Endogenous variables	10 percent increase in irrigated area (s5.1)	10 percent rise in capital inputs and marketing infrastructure (s5.2)	Irrigated land up 10 percent plus 5 percent rise in inputs and marketing (s5.3)	20 percent fertilizer subsidy (s5.4)
	Scenarios for change in exogenous variables			
National income per capita	1.71	−0.20	1.61	1.30
Output				
Total	2.72	0.81	3.12	1.26
Rice	0.64	−1.24	0.02	0.34
Wheat	5.14	1.34	5.81	1.29
Coarse cereals	1.88	2.12	2.94	−2.13
Other crops	3.48	1.47	4.22	2.47
GNP deflator	−5.76	−2.95	−7.23	−1.13
Prices				
Rice	−6.93	−2.11	−7.98	−1.76
Wheat	−12.77	−5.34	−15.44	−1.78
Coarse cereals	−9.39	−7.19	−12.98	1.25
Other crops	−6.38	−3.93	−8.34	−1.94
Wage rate	0.71	0.42	0.92	−1.90
Employment	0.44	0.25	0.56	−0.77
Wage bill	1.14	0.67	1.48	−2.67
Profits	−4.79	−8.20	−8.89	5.58
Income per capita (by quartile)				
Rural				
Poorest	2.92	1.64	3.74	−0.35
Second	1.71	0.03	1.73	0.75
Third	0.90	−1.02	0.39	1.54
Richest	−0.67	−2.39	−1.87	2.54
Urban				
Poorest	6.04	2.66	7.37	0.60
Second	5.73	2.56	7.01	0.74
Third	5.15	2.38	6.35	0.60
Richest	3.50	1.73	4.37	0.40
Per capita cereal consumption				
Rural				
Poorest quartile	2.57	1.21	3.18	−0.74
Richest quartile	−0.07	−1.30	−0.72	0.60
Urban				
Poorest quartile	5.59	2.25	6.72	0.06
Richest quartile	−0.38	−0.95	−0.86	−0.33
Aggregate per capita cereal consumption	1.84	0.04	1.86	0.07

Note: The values shown are the percentage changes in the endogenous variables from their base case level, as the result of the induced change in the exogenous variables shown in the column headings.

All income, output, price, wage, profit, and consumption variables are real values.

The income groups shown are expenditure quartiles for rural and urban populations separately. The four rural expenditure quartiles together constitute 0.8009 of the total population, while the four urban quartiles include 0.1991 of the total population.

irrigation, but the disparities among the income groups are substantially less because the effect on output is smaller.

Scenario 5.3 combines the two previous scenarios, except that investment in irrigation is accelerated twice as much (10 percent) as investment in capital and marketing (5 percent). Since the distributional effects of scenarios 5.1 and 5.2 are so similar, their combined effects are largely a matter of increased magnitudes.

Scenario 5.4 portrays a simple fertilizer subsidy scheme in which government pays 20 percent of the actual cost of fertilizers.[8] Since we assume that the supply elasticity of fertilizers is high (4.0), this scheme results in a considerable shift of the supply curve. We also assume that fertilizer is not rationed or is sold in the black market at higher prices. In other words, the subsidy actually reaches the farmers and alters their fertilizer use.

Under this scenario, aggregate agricultural output increases by about 1.3 percent with the output gains concentrated in wheat and in other commodities. Output of coarse cereals, which are not fertilizer-responsive, declines by 2.1 percent. The GNP deflator declines by 1.1 percent, which leads to gains for urban consumers. Fertilizer is substituted in part for labor, and the real wage bill declines by 2.7 percent. Thus the rural poor lose, since their losses in wages outweigh their gains as consumers. The rural rich, however, obtain a gain in income because of higher farm profits. For them, the fertilizer subsidy and lower wages more than offset the negative effect of smaller output prices.

Note, too, that the rural poor's cereal consumption declines by more than their real income loss because the prices of coarse cereals rise.

Taxation and Redistribution Scenarios

Scenarios 6.1 and 6.3 (see table 6) postulate various forms of taxation each of which raises Rs12 billion (billion is 1,000 million). It is assumed that the money is used for purposes which do not affect agricultural demand or supply.

In scenario 6.1 a land tax of 10 percent of residual farm profits is levied. Residual farm profits are considered a proxy for land rents.

In scenario 6.2 the assumption is that a progressive income tax is levied on rural residents alone. In order to raise Rs12 billion at 1973–74 prices, rates of 3.1 and 6.2 percent on the nominal incomes of the upper two rural quartiles are required. The two poorer quartiles are untaxed.

Scenario 6.3 involves imposing an excise tax on nonagricultural goods. This is achieved by means of an exogenous increase of 9.7 percent in the price index for nonagricultural goods. Unlike the land tax or the income tax, the excise tax would also fall on the urban income groups.

Scenarios 7.1 to 7.3 are income redistribution schemes that assume an increase of 30 percent in the nominal per capita income of the poorest rural

8. Indian fertilizer subsidy policy is complex, and a more detailed analysis is required to assess its exact impact.

Table 6. *Simulated effects of changes in taxation and income redistribution policies*
(percentage change)

	Scenarios for change in exogenous variables						
				30 percent income redistribution			
Endogenous variables	*10 percent land tax (s6.1)*	*Rural income tax (s6.2)*	*Nonagricultural excise tax (s6.3)*	*From 10 percent land tax (s7.1)*	*From rural income tax (s7.2)*	*From nonagricultural excise tax (s7.3)*	*From land transfer (s8.1)*
National income per capita	−3.14	−2.91	−2.67	0.32	0.55	0.79	0.57
Output							
Total	−0.29	−0.25	−0.02	0.12	0.17	0.39	0.18
Rice	−1.00	−0.81	−0.27	0.68	0.87	1.41	1.01
Wheat	−3.17	−2.84	−2.06	0.86	1.20	1.97	1.35
Coarse cereals	3.59	3.27	2.24	−0.12	−0.44	−1.47	−0.60
Other crops	−0.16	−0.18	0.03	−0.26	−0.28	−0.07	−0.32
GNP deflator	−7.11	−6.05	2.19	3.68	4.74	12.98	5.19
Prices							
Rice	−10.47	−8.80	−0.39	6.01	7.67	16.09	8.45
Wheat	−14.07	−12.15	−3.51	6.46	8.38	17.03	9.21
Coarse cereals	−5.61	−4.44	3.25	5.61	6.78	14.46	7.25
Other crops	−8.60	−7.41	−0.32	3.75	4.95	12.03	5.41
Wage rate	0.36	0.40	−0.54	0.57	0.61	−0.34	0.63
Employment	0.28	0.27	−0.09	0.10	0.09	−0.28	0.08
Wage bill	0.64	0.67	−0.63	0.66	0.69	−0.61	0.72
Profits	−25.10	−12.84	−5.03	−3.37	8.89	16.70	9.76

Income per capita (by quartile)							
Rural							
Poorest	0.58	1.46	−1.00	27.87	28.74	26.28	28.62
Second	−2.99	−0.46	−2.56	−2.25	0.28	−0.82	0.31
Third	−5.41	−4.88	−2.12	−2.39	−1.86	0.90	1.37
Richest	−10.10	−10.76	−3.51	−2.24	−2.89	4.35	−4.31
Urban							
Poorest	5.82	5.59	−1.19	−3.62	−3.85	−10.63	−4.23
Second	6.72	6.09	−1.81	−3.57	−4.20	−12.10	−4.63
Third	5.98	5.44	−2.57	−3.03	−3.57	−11.58	−3.93
Richest	3.82	3.66	−4.54	−1.88	−2.03	−10.24	−2.24
Per capita cereal consumption							
Rural							
Poorest quartile	0.59	0.98	−0.37	16.52	16.91	15.57	16.73
Richest quartile	−3.10	−3.36	0.62	−1.06	−1.32	2.66	−1.82
Urban							
Poorest quartile	4.86	4.54	−0.52	−3.47	−3.78	−8.84	−4.15
Richest quartile	−0.29	−0.21	−0.04	−0.38	−0.31	−0.13	−0.36
Aggregate per capita cereal consumption	−0.59	−0.46	−0.20	0.58	0.71	0.97	0.78

Note: The values shown are the percentage changes in the endogenous variables from their base case level, as the result of the induced change in the exogenous variables shown in the column heading.

All income, output, price, wage, profit, and consumption variables are real values.

The income groups shown are expenditure quartiles for rural and urban populations separately. The four rural expenditure quartiles together constitute 0.8009 of the total population, while the four urban quartiles include 0.1991 of the total population.

quartile. In scenario 7.1 the source of the added 30 percent is the land tax discussed above, which is just sufficient to finance the increase. In scenario 7.2 the progressive income tax is used to finance the increase. In scenario 7.3 the source is the excise tax at the rate of 9.7 percent.

The land tax translates into substantial price drops (the GNP deflator is -7 percent) but only a minimal decline in aggregate agricultural output (-0.3 percent). The decline in residual farm profits is 25 percent. Urban groups gain from the price decline, while rural groups (except for the poorest) suffer a real income loss, the more so the richer they are. This income redistribution leads to a redirection of production toward coarse cereals (3.6 percent) and away from rice and wheat (-1 and -3.2 percent respectively).

Qualitatively, the effects of the income tax are very similar to those of the land tax. The only exception is the much smaller effect of the income tax on farm profits, an effect that is the result of reduced final demand rather than a direct tax effect. Because the rural poor escape direct taxation and the rural rich carry the entire tax burden, the income distribution effect of the income tax is more progressive than that of the land tax.

The excise tax has a more even incidence than the other taxes, since it also falls on the urban groups. The urban rich and the rural rich are the groups whose incomes are reduced the most, -3.5 and -4.5 percent respectively.

Depending on how taxes are levied, the planned gain of 30 percent in income for the rural poor is somewhat eroded. The gain from the excise tax falls to 26.3 percent, the gain from the land tax falls to 27.8 percent, and the gain from the income tax falls to 28.7 percent. This happens because the rural poor have a higher propensity to consume food than the rich, and their increased demand for food causes food prices to rise. In the land tax and income tax scenarios, the richer rural groups lose very little because rising food prices increase farm profits. In fact, the rich rural group loses only about as much as the untaxed rich urban groups, whose loss stems from rising food prices. These higher prices mean, in effect, that the urban groups end up paying part of the income transfer to the rural poor. In the excise tax scenario, the price level rises particularly fast (13 percent) because increases in food prices and the excise tax both affect the price level. Therefore, almost the entire burden of an excise tax would be placed on the urban groups. Large farmers would show a net gain as a consequence of the increased food demand of the rural poor.

In scenario 8.1, sufficient land is transferred from the fourth rural quartile (the richest) to the first quartile to give the rural poor an initial income boost of nearly 30 percent. The effects are very similar to the land tax and income tax scenarios, although the rural rich lose a bit more, since they are the only taxed group.

The taxation and income redistribution scenarios show that a substantial increase in the income of the rural poor could be achieved that would cause only small losses—or, in some cases, even a net gain—for the rural rich. This is an important, and initially counterintuitive, result that is again critically dependent on letting food prices rise. If, for example, the government decided to accommodate the increased food demand via imports, large farmers would inevitably lose as their profits would not increase.[9]

V. Conclusion

During the past two decades, Indian agricultural output has grown at an annual rate of 2.7 percent, which is extremely high by international standards. Production is now at a level that would be sufficient to feed India's population, which has increased by 2.2 percent annually. The technical changes associated with the Green Revolution have been an important part of this increased output, and there is no question that, had they not occurred, India would be far worse off today than it is. During the early Green Revolution period, the real per capita income of the rural population of India rose by about 8 percent. However, these gains were rapidly eroded. The sobering point is that in 1980–81 real rural per capita income appears to have been only about 2 percent higher than in 1960–61.

The early productivity gains of the Green Revolution were retained by the agricultural sector because Indian policymakers used these gains to reduce imports of foods. Food prices therefore continued to rise slightly. But when near self-sufficiency was reached, all the extra output had to be absorbed domestically, food grain prices declined, and terms of trade moved substantially against agriculture. The benefits of the productivity gains were thereby transferred to consumers, a classic case of the agricultural treadmill.

The early Green Revolution period was associated with a sharp rise in residual farm profits, while the real wage bill rose much more modestly. The real income gain of that period was distributed regressively; large farmers gained the most while the rural poor gained very little. However, the subsequent rapid drop of about 25 percent in residual farm profits reduced the per capita incomes of the rural rich to their 1960–61 levels. By 1980–81, both the absolute level of real rural per capita income and its distribution appear to have returned to about what they were in 1960–61.

Real rural wages (as measured by actual data) appear to have risen somewhat during the early Green Revolution but then dropped back so that by 1980–81 they were barely above the 1960–61 level. Agricultural employment (as measured by the model) rose substantially but at a rate slower than rural labor force growth. The simulations show clearly that the main reasons for these trends are the adverse demographic trends and the insufficient growth in nonagricultural employment. The rural poor did not lose too much only because they shared

9. Note that the government can also alter the income distribution by direct food distribution at subsidized prices to rural or urban groups. These issues are discussed in a separate paper (Binswanger and Quizón 1986).

somewhat in farm profit growth, in nonagricultural income growth, and in the consumer benefits from declining agricultural terms of trade.

There were probably subgroups of the rural poor, including the totally landless agricultural workers, who suffered more severely than indicated. In addition, several areas of the country did not participate in the adoption of Green Revolution technology and their farmers must have been hurt by the decline in agricultural prices. We are currently investigating interregional issues, but it is evident that the simulations presented here have obscured the sharper declines in income experienced by these subgroups and regions.

A further sobering point is that some intuitive notions of how agricultural development trends or policies affect income distribution are likely to be wrong. Much of the debate on the distributional impact of technical change has concentrated excessively on the nature of the technical changes. Our analysis suggests that trade policy is a far more important determinant of income distribution. All growth-oriented policies or technical changes tend to benefit net buyers of food if the additional agricultural output is absorbed domestically rather than used to reduce imports or increase exports. Forcing domestic absorption has been the policy customarily pursued by India except during the early part of the Green Revolution, when agriculture production gains were used largely to reduce imports. Since the gains that occurred later were not used to expand exports, net food buyers in both rural and urban areas benefited.

This evidence, however, does not imply the general superiority of policies prohibiting external food trade for equity objectives. Given a shortfall in food production, rather than the sharp increases examined here, use of food imports to avert shortages and a marked rise in prices will *serve* equity goals.

There are, of course, differences in the impact of different technical changes or investment policies. As intuition would suggest, technical changes resulting in greater production of coarse cereals benefit poor rural consumers more than technical change directed toward improving production of other types of food. And investment in irrigation has a greater effect on the demand for labor than a fertilizer subsidy, which tends to encourage the substitution of fertilizers for labor.

But none of the agricultural development measures can affect rural labor demand or wages nearly as much as changes in population growth or growth in the demand for nonagricultural labor. This does not mean, of course, that we should not pay attention to the selection of agricultural techniques or other employment determinants. It simply suggests that major improvements in the incomes of the rural poor must eventually come mainly from demographic changes and growth in nonagricultural employment.

The only other avenue for substantially affecting incomes of the poorest group, the rural poor, are direct income transfers or land redistribution. Such transfers increase food demand and under closed economy conditions lead to rising food prices, which thereby erode the gains to the rural poor to roughly 90 percent of the initial nominal transfer. More important than this erosion of benefits, however, is the effect these price changes have on shifting the burden of the tax required to finance the income or asset transfers. If the rural rich are the source of taxes (or land) to finance the income (or land) transfer, the rise in food prices and therefore in farm profits drastically reduces the real incidence of the tax on them and shifts it to the urban groups. In the case of more broad-based taxes such as an excise tax, the rural rich can even become net beneficiaries from the income distribution because the increase in farm profits exceeds their tax burden. Note that these conclusions would not hold in a free trade situation in which food prices remained at a constant level. Again, the crucial nature of the trade decision on the real outcome of government policies must be emphasized.

Appendix A. The Model in Mathematical Terms

The model is an extension of the theoretical model described in Quizón and Binswanger (1983). Producer behavior is represented by a system of output supply and factor demand equations called the *producer core*. Analytically, the producer core is derived from a variable profit function $\Pi^* = \Pi^*(V, Z, \tau)$, where Π^* is maximized variable profits, $V = (P, W)$ is the vector of prices of outputs (P) and variable inputs (W), Z is a vector of fixed inputs, and τ is a technology index (appendix table 1 lists definitions of the symbols used in the model). The output supply and factor demand curves are derived from Π^* via Shepard's lemma; that is, the vector of outputs (Y) and (negative) variable inputs ($-X$) is written as

$$Q = [Y, -X] = \frac{\partial \Pi^*}{\partial V}.$$

In terms of rates of changes, they are written as

$$Q_i' = \sum_j \beta_{ij} V_j' + \sum_g \beta_{ig} Z_g^* + E_i' \qquad i \epsilon O,\ VI \tag{1}$$

O is the set of outputs and VI the set of variable inputs. The prime notation X' of a variable X indicates the total rate of change over time of variable X. The star notation X^* refers to the rate of change of an exogenous variable or to the exogenous component of an endogenous variable. β_{ij} are the elasticities of supply (or demand) of an output i (or factor i) with respect to a price j. The Zs are exogenous variables and fixed inputs affecting producer behavior, and the β_{ig} are supply or demand elasticities with respect to those fixed inputs. Some of the Z variables are subject to government policy. $E_i' = \partial Q_i / \partial \tau \ 1/Q_i \ \partial \tau / \partial \tau$ are the technology shifters of the supply and factor demand equations if fixed inputs are held constant. (For a detailed discussion of these technology concepts used, see Quizón and Binswanger 1984.)

Output demand is treated in a more disaggregated fashion. Let $k = 1, \ldots, K$ refer to income groups. Then total final demand is defined as

$$Y_i = \sum_k Y_{ik} \qquad i \epsilon O \tag{2}$$

Appendix Table 1. *Symbols Used in the Model*

E_i'	=	$\frac{\partial Q_i}{\partial \tau} \frac{1}{Q_i} \frac{\partial \tau}{\partial t}$ = technology shifters, that is, shifts in output supplies and factor demands for given fixed input levels. These are profit function definitions.
G	=	square matrix of elasticities and shares
K^*	=	column vector of exogenous shifter variables
L	=	labor services
M	=	total nominal income
m	=	real per capita income
MN	=	nonagricultural income
N	=	population
NA	=	nonagricultural commodities
P	=	output prices
$\bar{P}$	=	output price indexes
Q	=	$[Y, -X]$ = vector of outputs and (negative) variable inputs
S	=	rent to fixed factor
s_i	=	share of output i in total revenue or share of factor i in input prices
t	=	time
U'	=	column vector of endogenous variables
V	=	$[P, W]$ = vector of output and variable input prices
W	=	wage rate or variable input prices
w	=	real wage rate
X	=	variable inputs
Y	=	outputs
y	=	per capita output
Z	=	fixed factors; Z_1 refers to land
τ	=	technology index
β	=	price elasticity of supply or demand in production (outputs and inputs respectively)
π	=	variable profit function
λ_{ik}	=	proportion of i from (by) group k
ϵ	=	price elasticity of factor supply
ℓ	=	labor supply per person
ϕ	=	variable profit shares
μ_{ik}	=	share of group k's consumer expenditures spent on commodity i
ν_k	=	share of real income accruing to group k

Modifiers of variables unless already defined above:

X	=	level
X, X^T	=	a column and a row vector of the X variables, respectively
X'	=	$\frac{dX}{dt} \frac{1}{X}$ = total rate of change (n growth rate) of variable X with respect to time
X^*	=	exogenous component of the rate of change of a variable (except that π^* stands for maximized variable profits)

Indexes and sets of inputs and outputs

g	=	shifter variables
i	=	commodities (outputs, inputs)
j	=	commodities (outputs, inputs)
k	=	income groups
K	=	set of income groups or their total number
O	=	set of outputs or total number of outputs
I	=	set of inputs or total number of inputs
VI	=	set of variable inputs or their total number

where Y_{ik} is the total demand of consumer group k. Rewriting equation 2 in terms of changes,

$$\text{(3)} \qquad Y_i' = \sum_k \lambda_{ik} Y_{ik}' \qquad i \epsilon O$$

where $\lambda_{ik} = Y_{ik}/Y_i$ is the proportion of commodity i consumed by income group k. The consumption of each income group is described by an income-group-specific consumer demand system:

$$\text{(4)} \qquad \underline{Y}_k = N_k \underline{y}_k(\underline{P}, m_k)$$

where the underbars denote a column vector of the variable; for example, $\underline{Y}_k = (Y_1, Y_2, \ldots, Y_O)$, N_k is the population in income group k, and y_{ik} is the per capita demand which depends on output prices and the per capita income of the income group. Transforming each equation into rates of changes leads to

$$\text{(5)} \qquad Y_{ik}' = y_{ik}' + N_k' = \sum_j \alpha_{ijk} P_j' + \alpha_{imk} m_k' + y_{ik}^* + N_k' \qquad i,j \epsilon O$$

Here, y_{ik}^* is an exogenous change in per capita demand of income group k, and α_{ij} and α_{im} are the price and income elasticities of final demand.

We assume that the population in each income group grows at an exogenous rate N_k^*. But the rural population grows via immigration or via diminished emigration and vice versa for the urban population. We assume this migration to be responsive to the real rural wage rate. Differentiating N_k with respect to time and the real wage and converting to rates of changes leads to

$$\text{(6)} \qquad N_k' = \epsilon_{mk} w' + N_k^* = \epsilon_{mk} (W_L' - \bar{P}_k') + N_k^*$$

where ϵ_{mk} is the migration elasticity into (or for the urban group, out of) the specific income group with respect to the real rural wage and $\bar{P}_k$ is an income-group-specific price deflator defined below. Let the rural income groups be indexed $k = 1, \ldots 4$ and the urban group by $k = 5, \ldots 8$. Total labor supply to agriculture is

$$L = \sum_{k=1}^{8} L_k,$$

or in rates of changes

$$\text{(7)} \qquad L' = \sum_{k=1}^{8} \lambda_{Lk} L_k'$$

where $\lambda_{Lk} = L_k/L$ is the proportion of labor supplied to agriculture by income group k. Labor supply of income group k is $L_k = \ell_k N_k$ where ℓ_k is total labor supply per person. Differentiating with respect to the real wage and time and converting to rates of change, we find

$$\text{(8)} \qquad L_k' = \epsilon_{\ell k} w' + \ell_k^* + N_k' = \epsilon_{\ell k} (W_L' - \bar{P}_k') + \ell_k^* + N_k'$$

where $\epsilon_{\ell k}$ is the total labor supply elasticities of income group k and ℓ^* is an exogenous shifter in the labor supply to agriculture of income group k.

The supply of bullocks is similarly aggregated as

$$X_i = \sum_{k=1}^{8} X_{ik}$$

Rates of change are aggregated as usual; that is,

$$X_i' = \sum_{k=1}^{8} \lambda_{ik} X_{ik}' \qquad i = \text{bullocks} \tag{9}$$

The supply of each input is only dependent on its own price, W_i; therefore,

$$X_{ik}' = \epsilon_{ik}(W_i' - \bar{P}_k') + X_i^* \qquad i = \text{bullocks} \tag{10}$$

While the model contains many fixed input (Z) variables, such as irrigation and rainfall (see appendix table 10), we treat land (indexed as Z_1) as the only fixed factor which is a recipient of residual farm profits. The change in residual farm profits per unit of land (rental rate of land) S' is derived residually from the profit function, a derivation given in detail in Quizón and Binswanger (1986).

$$S' = \sum_i \phi_i V_i' + \Sigma \phi_i Q_i' - Z_i^* \qquad i \epsilon O,\ VI \tag{11}$$

where

$$\phi_i = \frac{Q_i V_i}{\Pi^*}$$

are variable profit shares, which are positive for outputs and negative for inputs.

Changes in income-group-specific consumer price levels $\bar{P}_k'$ can be related to the endogenous changes in agricultural output prices as follows:

$$\bar{P}_k' = \sum_{i\epsilon O} \mu_{ik} P_i' + \sum_{i\epsilon O} \mu_{NAk} P_{NA}^* \tag{12}$$

where μ_{ik} is the share of total consumer expenditures spent on commodity i by income group k. The subscript NA refers to nonagricultural commodities. The GNP deflator $\bar{P}$ is derived in the same way by dropping the k subscripts.

The nominal income of income group k is M_k and is defined as the sum of all net factor incomes accruing to the group plus nonagricultural incomes MN.[10]

$$M_k = \sum_{i\epsilon VI} X_{ik} W_i + Z_{lk} S + MN_k \tag{13}$$

where Z_{1k} is land supplied by group k.

10. Note that we treat all rural labor supply as "agricultural" labor because we assume wage equalization between the agricultural and nonagricultural *rural* labor markets.

Real per capita income is derived by dividing by the number of people and the consumer price index: that is,

$$m_k = M_k/\bar{P}_k N_k \tag{14}$$

Differentiating 13 and 14 totally and converting to rates of changes leads to

$$m'_k = \sum_{i \in VI} \delta_{ik}(W'_i + X'_{ik}) + \delta_{Sk}(S' + Z^{*\prime}_{1k}) - \bar{P}'_k - N'_k + \delta_{MNk} MN^{*}_k \tag{15}$$

where the δ_i are the shares of net income arising from the respective source.

The real per capita income of India's rural and urban population is defined as

$$m = \sum_k \lambda_{Nk} m_k \tag{16}$$

where $\lambda_{Nk} = N_k/\sum_k N_k$ are the initial shares of group k in the total population. Differentiating and converting into rates of changes leads to

$$m' = \sum_k \lambda_{Nk} \frac{m_k}{m} m'_k = \sum_k \nu_k m'_k \tag{17}$$

where ν_k is the proportion of real income accruing to group k.

Note that m' is not equal to the conventional definition of a change in real per capita income, which would be

$$m' = M' - N' - \bar{P}' \tag{18}$$

where $\bar{P}'$ is computed from the equivalent of equation 12 but the k subscript is dropped, and M is defined as in equation 13 but again the k subscript is dropped. The difference between equations 17 and 18 is that 17 utilizes real income weights, for which each group's real income is deflated by a group-specific price deflator. Thus 17 is closer to a measure of a change in real per capita welfare than is 18.

The model treats India as a closed economy with respect to agricultural commodities except that trade by the government is allowed and is easily treated as a fixed addition to and reduction from domestic supply. The full model consists of equations 1, 3, 5, 6, 7, 8, 9, 10, 11, 12, 15, and 17.

The equation system can be exhibited in matrix form:

$$GU' = K^* \tag{19}$$

where G is a square matrix of elasticities and shares, U' is the column vector of endogenous variables, and K^* is a column vector of exogenous shifter variables. (For simpler examples of such full systems, see Quizón and Binswanger 1983, 1986.) The effect of a shift in an exogenous variable on the endogenous variables in the system can be solved as

$$U' = G^{-1}K^* \tag{20}$$

which exists so long as the matrix G is nonsingular.

Appendix B. Data and Parameter Values

The data used to compile our core (or G) matrix come from a variety of sources.[11] The agricultural commodities, rice, wheat, inferior cereals, and other crops, are exhaustive in that they account for all *crop* production in the agricultural sector. Livestock products are aggregated into "other agricultural commodities."

The commodity-specific output supply and the fertilizer and labor demand elasticities for the semiarid tropics (SAT) are from Bapna, Binswanger, and Quizón (1984); for North India and the eastern rice region (ER) from Evenson (1981); and for the coastal rice region (CR) of South India from unpublished estimates. Estimation equations were derived from a normalized quadratic profit function on which all regularity conditions were imposed, except for the condition of convexity of the resultant Hessian matrices. The estimates were therefore adjusted in an *ex post* manner in order to satisfy this convexity constraint, following trial and error procedures described in Quizón and Binswanger (1984).

The bullock power demand elasticities have been estimated in Evenson and Binswanger (1984). Only the own-price elasticity and the cross-price elasticity with respect to labor are available for bullock power demand.

The output demand elasticities are from Binswanger, Quizón, and Swamy (BQS, 1984) and are averages for all India. Original price coefficient estimates in the reported demand equations were first adjusted following trial and error procedures to satisfy convexity restrictions. Then, from the twenty-eighth round of the National Sample Survey (28 NSS) *Tables on Consumer Expenditures*, the average commodity prices, the per capita quantities consumed, and the real per capita expenditures and incomes of each of our defined expenditure quartiles were computed. These were used with the adjusted convex price coefficient estimates and the income coefficient estimates from BQS to obtain all expenditure-quartile-specific output price and income elasticities of demand.[12] Total consumption by commodity and by group, computed straightforwardly from the 28 NSS, was used to obtain the λ_{ik} output consumption weights in equation 3 and the μ_{ik} weights in equation 12.

The 1970–71 National Council for Applied Economic Research (NCAER) Additional Rural Income Survey (ARIS) is a national rural household survey that contains a wealth of data, including information on household ownership of different agricultural factors of production, household incomes by income source, and costs of agricultural production by factor of production. The survey does contain data on hired labor but not, however, on family labor input. We therefore used data on family labor input by farm size group from the Farm

11. All notations used in this appendix are defined in appendix A.

12. For the highest income group, urban 4, the estimated elasticities for coarse cereals had high negative values. These values were reduced to a minimum of -1.

Management (FM) studies and matched each household in the NCAER survey with the corresponding farm size group in the FM study which most closely resembled the agroclimatic features of the district in which the NCAER household resided. For a number of semi-arid districts, we used family labor data from the more recent village studies of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). With this addition, the NCAER survey enables computation of the λ_{ik} input supply weights in equations 7 and 9, the π_i profit shares in equation 11, and the δ_{ik} income weights in equation 15. Pal and Quizón (1983) describe in detail how all these shares are computed from the NCAER-ARIS survey.

The only unaccounted parameters in our G matrix thus far are the input supply elasticities, that is, ϵ_{ik} in equations 6, 8, and 10. On the basis of Rosenzweig's (1980) econometric estimates, we assume ϵ_{lk} to be equal to 0.3. The migration elasticities, ϵ_{mk}, are computed from Dhar (1980) and are equal to 0.1083 for the rural groups and -0.4356 for the urban groups.[13] For bullock labor, the own-price elasticity is assumed to be equal to 0.4993, that is, the average of the value weighted sums of the own-price elasticities of supply for agricultural outputs in each agroclimatic region. This follows from the notion that bullocks are reproducible out of agricultural output. Finally, the fertilizer supply elasticity is set at 4.0, a high value which reflects opportunities for international trade.

The most important elements of our G matrix are given in appendix tables 3 through 9. All parameters pertaining to cost, income, and factor supply shares are listed in Pal and Quizón (1983). The β_{ig} matrix (equation 1) of shifter variables is listed in appendix table 10. These elasticity estimates are from the same estimation equations used to construct the matrix of output supply and variable input demand elasticities. The complex K^* vector of exogenous shifter variables (equation 19) can be reconstructed from the appendix tables and other data sources that already have been mentioned.

13. Quizón and Binswanger (1984) explain how these migration elasticities were computed from Dhar's study.

Appendix Table 2. *Agroclimatological Regions of India Showing the States, Union Territories, and Districts that Comprise Them*

Agroclimatological region	*State or union territory*	*Districts*[a]
Semiarid tropics (SAT)	Andhra Pradesh	Adilabad, Nizamabad, Karimnagar, Medak, Warangal, Mahbubnagar, Hyderabad, Nalgonda, Khammam, Kurnool, Guntur, Vishakapatnam, Anantapur, Cuddapah, Ongole, Nellore, Chitoor
	Gujarat	All
	Karnataka	Bidar, Gulbarga, Bijapur, Belgaum, Dharwar, Raichur, Shimoga, Bellary, Chikmagalur, Chitradurga, Hassan, Tumkur, Mandya, Mysore, Bangalore, Kolar
	Madhya Pradesh	All
	Maharashtra	All
	Rajasthan	All
	Tamil Nadu	Dharmapuri, The Nilgiris, Coimbatore, Salem, Tiruchirapalli, Pudukkottai, Madurai, Ramanathapuram, Tirunelveli
	Dadra and Nagar Haveli	—
Eastern rice (ER)	Arunachal Pradesh	All
	Assam	All
	Bihar	All
	Manipur	All
	Meghalaya	All
	Mizoram	All
	Nagaland	All
	Orissa	All
	Tripura	All
	Uttar Pradesh	Jalaun, Jhansi, Hamirpur, Banda, Fatehpur, Rae Bareli, Sultanpur, Faizabad, Basti, Allahabad, Pratapgarh, Jaunpur, Azamgarh, Gorakhpur, Mirzapur, Varanasi, Ghazipur, Ballia, Deoria
	West Bengal	All
Coastal Rice (CR)	Andhra Pradesh	Srikakulam, East Godavari, West Godavari, Krishna
	Goa	—
	Karnataka	North Kanara, South Kanara, Coorg
	Kerala	All
	Pondicherry	—
	Tamil Nadu	Chingliput, North Arcot, South Arcot, Thanjavur, Kanyakumari
Northern wheat (NW)	Chandigarh	—
	Delhi	—
	Haryana	All
	Himachal Pradesh	All
	Jammu and Kashmir	All
	Punjab	All
	Uttar Pradesh	Dehradun, Saharanpur, Bijnor, Nainital, Muzaffarnagar, Meerut, Moradabad, Rampur, Bulandshahr, Budaun, Bareilly, Pilibhit, Mathura, Aligarh, Agra, Etah, Mainpuri, Farukhabad, Shahjahanpu, Kheri, Etawah, Hardoi, Sitapur, Kanpur, Unnao, Lucknow, Barabanki, Bahraich, Gonda

— Not applicable.

a. For those states that fall into two agroclimatological regions, districts are allocated and identified individually.

Appendix Table 3. *Price Elasticities of the Producer Core for All India*

	Prices						
Quantities	*Rice*	*Wheat*	*Coarse cereals*	*Other crops*	*Fertilizer*	*Labor*	*Bullocks*
Rice	0.5531	−0.1280	−0.1271	−0.1834	−0.0206	−0.0940	0.0000
Wheat	−0.0900	0.4454	−0.1583	−0.0879	−0.0614	−0.0479	0.0000
Coarse cereals	−0.2280	−0.1088	0.7554	−0.2039	0.1791	−0.3986	0.0000
Other crops	−0.1632	−0.0320	−0.0652	0.2955	−0.1011	0.0663	0.0000
Fertilizer	0.0026	0.1203	−0.4635	0.7525	−0.8355	0.4278	0.0000
Labor	0.1019	0.0228	0.2045	−0.0489	0.0753	−0.4782	0.1225
Bullocks	0.0000	0.0000	0.0000	0.0000	0.0000	0.1335	−0.4041

Note: Elasticities are computed at base year 1973–74 prices and quantities. Estimates are aggregated from Evenson (1981), Evenson and Binswanger (1984), and Bapna, Binswanger, and Quizón (1986).

Appendix Table 4. *Own-Price and Expenditure Elasticities of Demand for All India, by Commodity and by Expenditure Quartile*

	Own-price elasticities of demand					*Income elasticities of demand*				
Expenditure quartile	*For rice*	*For wheat*	*For coarse cereals*	*For other food*	*For Nonfood*	*For rice*	*For wheat*	*For coarse cereals*	*For other food*	*For nonfood*
Rural 1	−0.7752	−0.7172	−0.6153	−0.8857	−0.5431	0.8196	1.1325	0.0653	1.2734	1.4408
Rural 2	−0.8311	−0.7247	−0.5507	−0.8077	−0.5529	0.7436	1.039	−0.3328	1.1540	1.5724
Rural 3	−0.8735	−0.7217	−0.4544	−0.7878	−0.5530	0.6825	1.0011	−0.5889	1.1158	1.5760
Rural 4	−1.0363	−0.7218	−0.0000	−0.7255	−0.5258	0.3768	0.8966	−1.0000	1.02154	1.5504
Urban 1	−0.8088	−0.7233	−0.5883	−0.8426	−0.5484	0.7771	1.0760	−0.1302	1.2040	1.5211
Urban 2	−0.8425	−0.7241	−0.5255	−0.8009	−0.5532	0.7271	1.0279	−0.4055	1.1420	1.5761
Urban 3	−0.9420	−0.7195	−0.2758	−0.7604	−0.5463	0.5672	0.9505	−0.9449	1.0682	1.5698
Urban 4	−1.1286	−0.6786	−0.0000	−0.7123	−0.4943	0.0844	0.7698	−1.0000	0.9827	1.5350

Note: Elasticities are computed at base year 1973–74 prices and quantities. Estimates are from Binswanger, Quizón, and Swamy (1984).

Appendix Table 5. *Shares of Commodities in Consumption of Each Expenditure Quartile*

Expenditure quartile	Commodity					
	Rice	Wheat	Course cereals	Other food	Nonfood	Total
Rural 1	0.3152	0.0847	0.1792	0.2643	0.1565	1.0000
Rural 2	0.2789	0.1021	0.1215	0.3128	0.1848	1.0000
Rural 3	0.2611	0.1029	0.0870	0.3364	0.2126	1.0000
Rural 4	0.1389	0.1254	0.0613	0.3661	0.3082	1.0000
Urban 1	0.2004	0.1525	0.0744	0.3875	0.1851	1.0000
Urban 2	0.2503	0.0935	0.0346	0.4004	0.2212	1.0000
Urban 3	0.1923	0.0955	0.0265	0.4073	0.2784	1.0000
Urban 4	0.0926	0.0634	0.0101	0.4261	0.4077	1.0000

Source: 28 NSS, *Tables on Consumer Expenditures,* 1973–74.

Appendix Table 6. *Share of Each Expenditure Quartile for All India, Total Consumption by Commodity*

Expenditure quartile	Commodity				
	Rice	Wheat	Coarse cereals	Other food	Nonfood
Rural 1	0.1405	0.0672	0.2125	0.0530	0.0505
Rural 2	0.2027	0.1293	0.2432	0.0998	0.0935
Rural 3	0.1938	0.1606	0.1877	0.1146	0.1152
Rural 4	0.1857	0.3131	0.2262	0.2186	0.2946
Urban 1	0.0476	0.0812	0.0507	0.0766	0.0394
Urban 2	0.0806	0.0616	0.0310	0.0910	0.0530
Urban 3	0.0837	0.0885	0.0308	0.1361	0.1097
Urban 4	0.0655	0.0985	0.0179	0.2103	0.2441
Total	1.0000	1.0000	1.0000	1.0000	1.0000

Source: 28 NSS, *Tables on Consumer Expenditures,* 1973–74.

Appendix Table 7. *Share of Each Expenditure Quartile in the Total Supply of Agricultural Inputs for All India*

Expenditure quartile	Agricultural input		
	Agricultural labor	Bullocks	Agricultural land owned
Rural 1	0.2380	0.0973	0.1137
Rural 2	0.2651	0.1514	0.1625
Rural 3	0.2466	0.2327	0.2553
Rural 4	0.2315	0.4402	0.4685
Urban 1	0.0118	0.0063	0.0669
Urban 2	0.0014	0.0097	0.0359
Urban 3	0.0051	0.0260	0.0320
Urban 4	0.0005	0.0358	0.0377
Total	1.0000	1.0000	1.0000

Sources: 1970–71 NCAER-ARIS survey; 26 NSS, *Tables on Landholdings, All India, 1981–82.*

Appendix Table 8. *Share in Total Income from Agricultural Inputs for All India by Expenditure Quartile*

	Agricultural input				
Expenditure quartile	*Agricultural labor*	*Bullocks*	*Residual farm profits*[a]	*Agricultural implements and machinery*	*Total agricultural income*
Rural 1	0.5283	0.0256	0.1132	0.0737	0.7408
Rural 2	0.4278	0.0254	0.2422	0.0567	0.7521
Rural 3	0.3383	0.0258	0.3298	0.0498	0.7437
Rural 4	0.2215	0.0241	0.4726	0.0646	0.7828
Urban 1	0.0713	0.0201	0.0069	0.0000	0.0983
Urban 2	0.0028	0.0099	0.0359	0.0000	0.0486
Urban 3	0.0061	0.0169	0.0320	0.0000	0.0550
Urban 4	0.0002	0.0093	0.0377	0.0000	0.0472
All Groups	0.2042	0.0157	0.2213	0.0380	0.4792

a. Defined as net returns to land.

Source: 1970–71 NCAER-ARIS survey.

Appendix Table 9. *Summaries of Agricultural and Demographic Data Used in the Model*

Share in total real income by expenditure quartile for all India

Rural 1	0.0898	Urban 1	0.0345
Rural 2	0.1425	Urban 2	0.0456
Rural 3	0.1752	Urban 3	0.0696
Rural 4	0.3185	Urban 4	0.1244
Total rural	0.7260	Total urban	0.2740

Share in the population by expenditure quartile for all India

Rural 1	0.2002	Urban 1	0.0498
Rural 2	0.2002	Urban 2	0.0498
Rural 3	0.2002	Urban 3	0.0498
Rural 4	0.2002	Urban 4	0.0498
Total rural	0.8009	Total urban	0.1991

Share of agricultural commodities in the value of total agricultural output for all India[a]

Rice	0.2666
Wheat	0.1073
Coarse cereals	0.1128
Other crops	0.5133

Share of agricultural inputs in the total cost of agricultural production for all India[b]

Agricultural labor	0.3258
Bullocks	0.1086
Residual farm profits	0.3088
Fertilizer	0.0331
Agricultural implements and machinery	0.0979

a. Data are from the national accounts.

b. Data are from the 1970–71 NCAER-ARIS survey.

Appendix Table 10. *Output Supply Elasticities with Respect to Exogenous Shifter Variables*

	Variable					
Commodity	*Rain*	*High-yield varieties*	*Irrigated area*	*Roads*	*Land*	*Capital*
Rice	0.3563	0.2755	0.0011	−0.2116	0.4801	−0.0458
Wheat	0.2178	0.3764	0.7965	−0.0488	0.2871	0.2566
Coarse cereals	−0.0575	−0.1931	0.2547	0.3207	0.2000	0.1025
Other crops	0.0750	0.0340	0.3629	0.0911	0.3056	0.1155
Fertilizer	0.1558	0.5606	0.6370	0.5422	0.0000	0.0000
Labor	0.0557	0.0526	0.0917	−0.0027	0.61291	0.0761
Bullocks	0.0578	0.0441	0.1022	0.0018	0.8882	−0.0183

Note: Elasticities are computed at base year 1973–74 quantities. Estimates are aggregated from Evenson (1981), Bapna, Binswanger, and Quizón (1984), and Evenson and Binswanger (1984).

Appendix Table 11. *Data Description and Data Sources for Counterfactual Analysis*

Variable or exogenous shock	*Additional Description*[a]	*Data source*[b]
	A. For actual price and quantity levels	
1. Rice production	Production index for rice	*Index Numbers of Area, Production, and Yield of Principal Crops in India—Cropwise,* Directorate of Economics and Statistics, Ministry of Agriculture
2. Wheat production	Production index for wheat	Same as 1 above
3. Coarse cereal production	Production index for coarse cereals	Same as 1 above
4. Other crop production	Production index for pulses and nonfood grains	Same as 1 above
5. All crop production	Production index for all crops	Same as 1 above
6. Fertilizer consumption	Computed as the sum of fertilizer production, net fertilizer imports, and net withdrawals from fertilizer stock	*Production, Imports, Distribution and Consumption of Fertilizers,* Fertilizer Association of India
7. Employment	Index of employed male rural workers	*Union Primary Census Abstract,* Census of India
8. Rice prices[c]	Wholesale price index for rice	*Index Numbers of Wholesale Prices in India,* Economic and Scientific Research Foundation
9. Wheat prices[c]	Wholesale price index for wheat	Same as 8 above
10. Coarse cereal prices[c]	Wholesale price index for coarse cereals	Same as 8 above
11. Other crop prices[c]	Production-weighted wholesale price index for other crops	Same as 8 above
12. Labor wages[c]	Index of money wage rate of agricultural laborers as defined in Jose (1974)	Jose (1974) and *Agricultural Wages in India,* Directorate of Economics and Statistics, Ministry of Agriculture
13. Prices of all commodities[c]	Consumption-weighted price index for all commodities (food and nonfood articles)	Same as 8 above
14. Real per capita income	Personal disposable income at constant prices divided by the population; this was used as an exogenous shock in section II	*Macroeconomic Aggregate and Population,* Central Statistical Office, Department of Statistics, Ministry of Planning
	B. For the Exogenous Shifters	
1. Rate of change in net cropped area		*Area under Principal Crops in India,* Directorate of Economics and Statistics, Ministry of Agriculture
2. Rate of change in population	Assumed to be equal across expenditure groups for given period of time	*Population by Sex, Sex Ratio, Percentage Decadal Variation of Population and Urban Population as a Percentage of Total Population,* 1901–1981, Census of India

3. Rate of change in capital used in agricultural production	Assumed to be equal across expenditure groups for given period of time. "Capital" refers to the value of household-owned livestock and machinery and implements used in agricultural production. How this variable was constructed is explained in the text.	*Gross Domestic Capital Formation by Industry of Use,* Central Statistical Office, Department of Statistics, Ministry of Planning *Proportion of Households Reporting and Average Value per Household of Individual Items of Assets and Liabilities as of 30th June 1971 according to Asset Groups,* Reserve Bank of India
4. Rate of change in the supply of draft animals in agricultural production	Assumed equal to the rate of growth in the total number of buffalo and cattle used for work only and assumed to be equal across expenditure groups for given period of time	*Total Buffalos and Cattle Used for Work,* Directorate of Economics and Statistics, Ministry of Agriculture
5. Rate of change in the supply of other inputs in agricultural production	Other inputs are taken to be all inputs other than land, labor, draft power, capital (as defined above), and fertilizer. Its rate of change is assumed to be equal to the rate of growth in the value of total agricultural production (at constant prices)	*Value of Output from Agriculture,* Central Statistical Office, Department of Statistics, Ministry of Planning
6. Rate of change in nonagricultural prices[c]	Nonagricultural prices are weighted averages of wholesale prices of nonfood articles	*Index of Wholesale Prices,* Economic and Scientific Research Foundation
7. Rate of change in the price of capital services and other inputs used in agricultural production[c]	Assumed equal to 6 above	Same as 6 above
8. Rate of change in nonagricultural income[c]	Assumed to be equal across expenditure groups for given period of time. Initial estimates of this exogenous shock were obtained from two independently computed indexes of nonagricultural incomes. However, this variable was treated as endogenous in section II (see text and appendix A)	*Net Domestic Production at Factor Cost by Industry of Origin,* Central Statistical Office, Department of Statistics, Ministry of Planning *Macroeconomic Aggregates and Population,* Central Statistical Office, Department of Statistics, Ministry of Planning
9. Rate of change in the domestic availability of rice caused by trade and buffer stock operations	Defined as the rate of change in the net available rice supply, that is, net imports of rice plus net releases from government-held stocks of rice	*Availability of Food Grains in India,* Directorate of Economics and Statistics, Ministry of Agriculture
10. Rate of change in the domestic availability of wheat caused by trade and buffer stock operations	Same as 9 above, but for wheat	Same as 9 above

(Table continues on the following page.)

Appendix Table 11. *Continued*

Variable or exogenous shock	*Additional Description*[a]	*Data source*[b]
11. Rate of change in the domestic availability of coarse cereals caused by trade and buffer stock operations	Same as 9 above, but for coarse cereals	Same as 9 above
12. Rate of change in the domestic availability of fertilizer caused by trade and buffer stock operations	Same as 9 above, but for fertilizer	*Production, Imports, Distribution, and Consumption of Fertilizers,* Fertilizer Association of India
13. Technical change in rice production	For 1960–61 to 1980–81 assumed to be equal to 75 percent of the rate of change in rice yield per hectare	*Index Numbers of Area, Production, and Yield of Principal Crops in India—Cropwise,* Directorate of Economics and Statistics, Ministry of Agriculture
14. Technical change in wheat production	Same as 13 above, but for wheat	Same as 13 above
15. Technical change in coarse cereal production	Same as 13 above, but for coarse cereals	Same as 13 above
16. Technical change in other crops production	Same as 13 above, but for other crops	Same as 13 above
17. Rate of change in the percentage of irrigated area	Percentage irrigated area: the ratio of gross area under irrigation to gross cropped area	*Gross Area under Irrigation by Crops,* Directorate of Economics and Statistics, Ministry of Agriculture *Area under Principal Crops in India,* Directorate of Economics and Statistics, Ministry of Agriculture
18. Rate of change in road density	Road density is defined as the ratio of road length (in kilometers) to total geographic area (in kilometers^2). "Roads" refers to all surfaced and motorable unsurfaced roads	*Extra-Municipal Roads (Classified According to Surface) Including National Highways Maintained by P. W.D. and Local Bodies and Roads Constructed in C.D. and N.E.S. Blocks,* Ministry of Shipping and Transport

a. Data values are three-year averages. They are indexed such that the average for the three years 1972–73 to 1974–75 is equal to 100.

b. Only table headings and the agency which reports them are listed here.

c. These variables are deflated by $\bar{P}$. See text of appendix A for further explanation.

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