Australian Journal of Agricultural Economics, Vol. 39, No. 1 (April 1995), pp 25-54

DOES TECHNICAL PROGRESS IN AGRICULTURE ALLEVIATE POVERTY? A PHILIPPINE CASE STUDY*

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We examine the impact of technical progress in agriculture on changes in measured poverty and aggregate welfare in a developing country. Using a small general equilibrium model, we show how the economic components of an observed change in poverty can be isolated to expose the significance of intersectoral linkages and the economic roles of changes in relative commodity and factor prices. Variation in the measured rate and distribution of poverty alleviation depends somewhat on the choice of poverty measure, but more substantively on structural assumptions and the effects of policy interventions in agricultural markets.

Introduction

Until recently population pressure on agricultural land resources in developing Asian countries was vented by agricultural expansion and intensification. In most of Asia the land frontier is now closed, and productivity gains are the primary sources of agricultural growth. Technical progress has taken two main forms: land quality improvement through irrigation, and adoption of new biological and chemical technologies — notably modern varieties (MVs) of rice and wheat. The two forms of technical progress are closely linked: the yield advantage of MVs over traditional varieties depends largely on the availability of irrigation. Yield gains from adoption of MVs on rainfed farms are only a small fraction of those on irrigated farms.

Agricultural growth is central to poverty alleviation in developing Asia. In most countries agriculture dominates employment, and the rural population includes a disproportionately large number of the poor. Moreover, rural poverty is concentrated among households reliant on produc-

* Funding support from the Australian Center for International Agricultural Research (Project No. 8838) is gratefully acknowledged. The authors wish to thank Ms Zita Albacea for excellent research assistance. Seminar participants at the Australian National University and the University of Wisconsin-Madison, and two anonymous referees made helpful comments. The authors hold each other responsible for any remaining errors.

tion from non-irrigated land — rainfed and upland — for most of their income (Balisacan 1993). How does technical progress concentrated in irrigated lowlands affect the poverty of these households and of the population as a whole?

The effects of technical progress cannot be analyzed independently of the policy setting in which they take place. In many developing countries, food self-sufficiency and cheap food prices have been pursued by means of restrictions on international trade coupled with domestic grain marketing operations, often by the same state trading agency. These interventions may thus have altered the commodity and input price impacts of technical progress in agriculture. How does food policy affect poverty alleviation as agricultural productivity increases?

In this paper we present a model to analyze the effects of technical progress on poverty alleviation among several stylized household groups in a representative developing country economy. Recognizing the importance of agriculture and its linkages to other sectors we employ a general equilibrium approach.

In an earlier study (Coxhead and Warr 1991) we presented a simple general equilibrium model in which agricultural production took place in two sectors distinguished by access to irrigation. We used this model to trace the effects of differential rates of technical progress in the two sectors on income distribution among factor-owning household groups.

The first contribution of this paper is to extend our earlier model to capture the effects of technical progress on the distribution of real expenditures not only among household groups, but also by expenditure classes within groups. We then calculate changes in poverty as functions of changes in real household expenditures. Our analysis decomposes a change in poverty into its economic determinants — adjustments in factor and commodity markets — thus clarifying the economic mechanisms of poverty alleviation.

The second contribution of this paper is to deepen our earlier analysis by examining the implications of varying key parameter values, structural assumptions, and policy settings. We compare measures of poverty alleviation and welfare change under weighting rules reflecting differing degrees of inequality aversion. We also vary the structural assumptions of the model, and find that significant differences in measured poverty alleviation arise. Our comparison of partial versus general equilibrium results highlights the importance of factor market assumptions for the measurement of poverty change. Finally, we show that trade restrictions in food markets substantially alter the measured rate of poverty alleviation due to technical progress, compared with the unrestricted trade case.

Philippine agricultural development patterns exemplify the irrigated/non-irrigated dichotomy used in our model (David and Otsuka 1990). Moreover, in recent years successive Philippine governments have declared both the absolute and the relative well-being of households to be important policy targets.[1] Accordingly, we base the parameter values of our model on Philippine estimates of poverty, income distribution and technical progress.

We set out and describe our model in the next section. In subsequent sections we review poverty and welfare measures, present and discuss simulation results and, concluding, point out some methodological and policy implications of our findings.

The Model

The model is of a small open economy in which three commodities are produced in four sectors. A single composite agricultural good is produced in each of two sectors distinguished by their access to irrigation. The third and fourth sectors produce services and manufactures. Production in each sector uses a specific factor as well as intersectorally mobile labor and capital inputs. The specific factors in agriculture are land endowments: irrigated land in sector 1 and non-irrigated land in sector 2. Factors specific to the services and manufacturing sectors (sectors 3 and 4) may be thought of as plant, buildings and other 'bolted down' capital not transferable in the short run. The model belongs to the Johansen class of general equilibrium models (Johansen 1960), in that it is linear in proportional changes of variables.

Our treatment of technical progress is as follows.[2] Let y_j be the output of sector j ($j = 1,\ldots,4$) and x^*_{ij} be the effective quantity of factor i used in sector j. Let commodity and effective factor prices be given by p_j and w^*_{ij} respectively. Actual factor quantities and prices (x_{ij} and w_{ij}) differ from effective quantities and prices by a factor proportional to the rate of technical change. Thus $x^*_{ij} = x_{ij}t_{ij}$ for quantities and $x^*_{ij} = x_i/t_{ij}$ for prices, where t_{ij} is the rate of augmentation of factor i used in sector j. Expressed as proportional changes in variables (denoted by $\hat{x} = dx/x$), changes in effective factor quantities and prices are defined by:

[1] Expressions of the need to alleviate poverty - not only for its own sake, but also as a means of stimulating domestic production - permeated the Philippine Medium Term Development Plan 1987-1992 (NEDA 1988). For example: 'Philippine development efforts in 1987-92 shall be principally directed toward the following goals: (a) alleviation of poverty, (b) generation of more productive employment, (c) promotion of equity and social justice, and (d) the attainment of sustainable economic growth' (p.11). 'A concerted attack against poverty is planned in the next six years. The economic recovery and the sustained growth targeted in the medium term will be achieved through policies, programs and projects that shall likewise ensure the promotion of social justice and the alleviation of poverty. Moreover, the main focus of government operations shall be the provision of basic needs of the population to ensure that these do not fall below minimum requirements' (p.32).

[2] Our description of technical change in this section is based on Dixon *et al.* (1981).

(1) $$\hat{x}^*_{ij} = \hat{x}_{ij} + \hat{t}_{ij}$$

(2) $$\hat{w}^*_{ij} = \hat{w}_i - \hat{t}_{ij}$$

By these definitions, a positive rate of technical change (an increase in some t_{ij}) increases the effective quantity of a factor and reduces its effective price.

We assume full employment of factors, given by market clearing conditions in which $\hat{x}^S_i$ denotes the proportional change in the aggregate supply of the i th mobile factor (i = 1,2) and $\hat{x}^3_j$ denotes the proportional change in the supply of the factor specific to sector j (j = 1,...,4). This implies, writing λ_{ij} for sector j 's initial share in employment of factor i:

(3) $$\sum_{j=1}^{4} \lambda_{ij} \hat{x}_{ij} = \hat{x}^S_i . \qquad (i = 1,2)$$

For the sector-specific factors:

(4) $$\hat{x}_{ij} = \hat{x}^S_{ij} . \qquad (i = 3; j = 1,\ldots,4)$$

The factor mobility assumptions above imply that for the two mobile factors capital and labor (i =1,2), factor returns are equated across sectors. Thus:

(5) $$\hat{w}_{ij} = \hat{w}_i . \qquad (i = 1,2; j = 1,\ldots,4)$$

For the sector-specific factor (i = 3), returns may differ across the four sectors. There are consequently six factor returns to be determined, for two variable and four specific factors.

Representative producers in each sector are assumed to minimize production costs subject to the constraints imposed by production technology. We assume constant returns to scale and constant elasticity of substitution (CES) technology. With three factors used in each sector — mobile labor and capital and a fixed factor — cost-minimizing factor demand functions can be written in proportional change form as:

(6) $$\hat{x}_{ij} = \hat{y}_j - \sigma_j(\hat{w}_{ij} - \sum_{k=1}^{3} \theta_{kj} \hat{w}_{kj}) - \hat{t}_{ij} + \sigma_j(\hat{t}_{ij} - \sum_{k=1}^{3} \theta_{jk}\hat{t}_{kj}), \qquad (j = 1,\ldots,4)$$

where σ_j is the elasticity of substitution in sector j and θ_{ij} is the share of factor i in total production costs of sector j. With one factor in fixed supply in each sector, (6) provides solutions for $\hat{x}_{ij}$ and $\hat{y}_j$ in each sector.

Competitive factor pricing ensures that total costs just equal gross receipts in each sector. This zero profit condition can be written in proportional change form as:

$$(7) \qquad \hat{p}_j = \sum_{i=1}^{3} \theta_{ij} (\hat{w}_{ij} - \hat{t}_{ij}), \qquad (j = 1,\ldots,4)$$

from which the change in unit return to each sector's specific factor is obtained as a residual after unit variable cost changes have been deducted from the commodity price change.

We identify seven groups of households according to their factor endowments. These are laborers, owners of capital in services and manufacturing sectors, farmers and landlords in irrigated agriculture, and farmers and landlords in non-irrigated agriculture. Laborers' endowments consist only of labor, but each other group is assumed to derive income from a combination of land, labor and capital. The small farmer groups own labor, some agricultural land in their own sector, and some mobile capital. Landlords' endowments consist of land and some mobile capital. The remainder of the mobile capital, as well as all the endowments of factors specific to sectors producing non-agricultural goods, are owned by the manufacturing and service sector capitalists. This asset distribution is summarized in Table 1.

TABLE 1

Household Groups and the Distribution of Asset Ownership

Code	Description	Asset Ownership
H=1	Laborers	Mobile labor only
H=2	S capitalists	Specific factor in services sector 3, some mobile capital
H=3	M capitalists	Specific factor in manufacturing sector 4, some mobile capital
H=4	Landlords 1	Mostly irrigated land, some mobile capital
H=5	Landlords 2	Mostly unirrigated land, some mobile capital
H=6	Farmers 1	Some irrigated land, some mobile labor and capital
H=7	Farmers 2	Some unirrigated land, some mobile labor and capital

Note: Estimated asset distributions are shown in Table 6.

To the extent that land is a component of their income, the fortunes of farmers and landlords are partially, although not completely, tied to profitability in the agricultural sector where their land is located. Laborers' incomes are affected by a change in a particular sector only insofar as it affects the economy-wide demand for their labor. Households owning specific factors in services and manufacturing have asset ownership positions comparable with those of landlords: although they derive some income from mobile capital, the greater portion comes from returns to sector-specific factors. Changes in sectoral profitability are thus the main determinants of changes in these households' absolute and relative prosperity.

For each household in factor-owning group h and expenditure class k (subsequently household hk) the change in its money income from factors is given by:

$$(8) \qquad \hat{m}^{hk} = \sum_{i=1}^{3} \sum_{j=1}^{4} \delta_{ij}^{hk} \hat{w}_{ij},$$

where δ_{ij}^{hk} denotes the share that earnings from factor i in sector j contribute to the total income of household hk. To focus on the effects of technical progress we assume that aggregate and household factor endowments are fixed in the short run, so for all households:

$$(9) \qquad \hat{x}_i^s = 0, \qquad (i = 1,2) \text{ and}$$

$$(10) \qquad \hat{x}_{ij}^s = 0. \qquad (i = 3: j = 1,...,4)$$

The data from which our asset distributions are constructed (NSO 1985) permit us to distinguish nine expenditure classes within each factor-owning group (Table 2). The initial distribution of expenditures within and across household groups is shown in Table 3 and Figure 1. Household expenditure patterns used in our analysis are set out later in the paper.

TABLE 2

Expenditure Classes

Number	Expenditure range (Thousands of Pesos per household per year, 1985 prices)
1	Less than 6.0
2	6.0 – 9.9
3	10.0 – 14.9
4	15.0 – 19.9
5	20.0 – 29.9
6	30.0 – 39.9
7	40.0 – 59.9
8	60.0 – 99.9
9	≥100.0

Note: Expenditure classes are taken from NSO 1985. Table 3

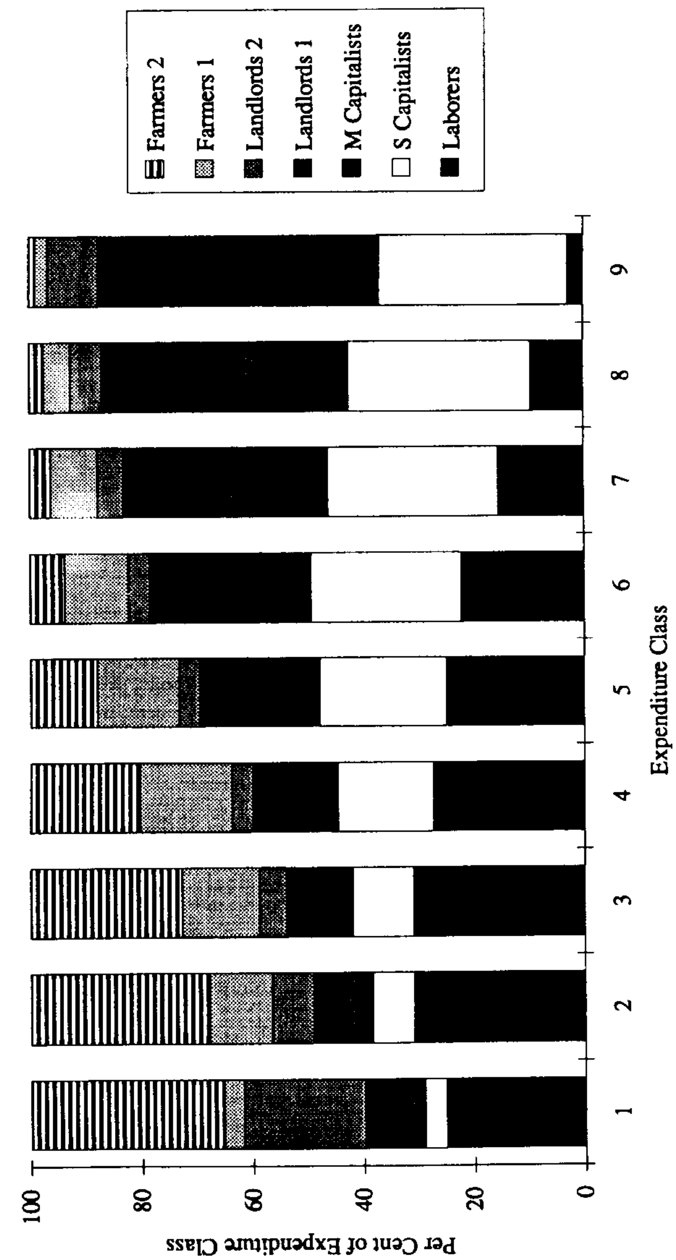
TABLE 3

Philippines: Population Distribution by Household Group and Expenditure Class, 1985

Household Group	Expenditure Class 1	2	3	4	5	6	7	8	9	Total	Mean Income (Pesos per yr)
	Relative Frequency (per cent of households)										
Laborers	0.95	3.49	5.57	4.28	4.90	2.46	1.65	0.61	0.10	24.01	21,931
S capitalists	0.15	0.85	1.97	2.70	4.52	3.00	3.26	2.10	1.20	19.75	41,961
M capitalists	0.09	0.50	1.18	1.44	2.62	1.95	1.91	1.20	0.65	11.55	41,451
Landlords 1	0.32	0.70	0.96	0.97	1.65	1.26	2.02	1.63	1.13	10.65	51,513
Landlords 2	0.83	0.85	0.87	0.58	0.72	0.43	0.49	0.35	0.31	5.43	31,621
Farmers 1	0.14	1.27	2.51	2.60	2.91	1.25	0.89	0.30	0.08	11.96	23,644
Farmers 2	1.31	3.63	4.89	3.10	2.38	0.70	0.41	0.18	0.04	16.65	16,475
Total	3.79	11.30	17.96	15.68	19.70	11.05	10.63	6.38	3.52	100.00	31,114

Source: Computed from NSO (1985). Data in NSO categories have been used to obtain a breakdown by the household groups shown in Table 1 as accurately as possible. Details may be obtained from the authors.

FIGURE 1
Distribution of Households by Expenditure Class



Source: Table 3

Households are assumed to maximize utility subject to budget constraints implied by (8). The optimization determines their consumer demands as functions of commodity prices and money incomes. Using c_j^{hk} the demand for good j by the members of expenditure class k in factor-owning group h, proportional changes in household demands are given as:

$$(11) \qquad \hat{c}_j^{hk} = \sum_{s=1}^{4} \varepsilon_{js}^{hk} \hat{p}_j + \eta_j^{hk} \hat{m}^{hk},$$

where ε_{js}^{hk} denotes household hk's (uncompensated) elasticity of demand for commodity j with respect to commodity s and η_j^{hk} denotes that household's expenditure elasticity of demand of demand for commodity j. Changes in aggregate consumption of each commodity are:

$$(12) \qquad \hat{c}_j = \sum_{h=1}^{7} \sum_{k=1}^{9} \varphi_j^{hk} \hat{c}_j^{hk},$$

where φ_j^{hk} is the initial share of consumption of j by expenditure class k in group h.

The two-way classification of households permits us to evaluate the effects of exogenous shocks on the distribution of income between household groups as well as across expenditure classes for any given group. For example, a laborer household in the poorest class has the same pattern of consumption as a small farmer household in the same class, and responds identically to *ceteris paribus* changes in commodity prices. A wage rise increases the nominal incomes of laborer households in all expenditure classes by an equal proportion. Since each class has a unique pattern of consumption, however, a wage rise relative to prices of goods consumed will have different effects on the *real* expenditures of the laborer household in the poorest expenditure class relative to those of laborers in higher classes. The division of households by both income and expenditure characteristics thus permits us to assess the impact of an exogenous shock on the level of poverty within each group, as well as changes in aggregate poverty.

Lastly, commodity market clearing and pricing are given by (13). The change in domestic consumption of each good, which equals the weighted sum of changes in domestic production and net imports (n_j), is:

$$(13) \qquad \hat{c}_j = \zeta_j \hat{y}_j + (1 - \zeta_j)\hat{n}_j, \qquad (j = 1,\ldots,4)$$

where the weight $\zeta_j = y_j / c_j$. Agriculture and manufacturing are assumed to be tradeables, with prices determined in world markets. For these goods, net imports adjust endogenously to satisfy (13). We assume services to be non-traded, so $\zeta_3 = 1$; domestic demand and supply changes must be equal and the market clears through adjustments in p_3.

Equations (1) to (13) define the core of our model. We treat rates of technical change as exogenous. The number of variables corresponding to each of equation sets (1) to (13) is 12, 12, 2, 4, 8, 12, 4, 63, 2, 4, 252, 4 and 4 respectively, a total of 383. The potentially endogenous variables of the system and their number (in parentheses) are: $\hat{x}^*_{ij}$(12), $\hat{x}_{ij}$ (12), $\hat{w}^*_{ij}$(12), $\hat{w}_{ij}$(12), $\hat{x}^s_i$ (2), $\hat{x}^s_{ij}$(4), $\hat{w}_i$ (2), $\hat{y}_j$ (12), $\hat{m}^{hk}$(63), $\hat{c}^{hk}_j$ (252), $\hat{c}_j$ (4), $\hat{n}_j$ (4), and $\hat{p}_j$ (4), a total of 387. The system is closed by choosing one of $\hat{n}_j$ and $\hat{p}_j$ to be exogenous for each of the four final goods. Thus, for the non-tradeable (good 3) the change in net imports is exogenously set at zero and the domestic price is determined endogenously; for each of the three tradeables we assume exogenous world prices and endogenous net imports. The core model is thus exactly identified.

It is important to confirm the internal consistency of a general equilibrium model. The joint clearing of all commodity and factor markets within the model may be verified as follows. Market clearing for all factors and the non-traded good are apparent from inspection of (3), (4) and (13). The clearing of the remaining markets for the two internationally traded goods (the trade balance constraint) may now be confirmed by noting that all consumers operate on their budget constraints and by invoking Walras' law.

The expenditure of household hk is given by

$$(14) \qquad e^{hk} = \sum_{s=1}^{4} p_s c^{hk}_s .$$

The proportional change in aggregate household expenditures is thus

$$(15) \qquad \hat{e}^{hk} = \sum_{s=1}^{4} \mu^{hk}_s (\hat{p}_s + \hat{c}^{hk}_s),$$

where μ^{hk}_s is household hk's budget share for good s. We wish to show that $\hat{e}^{hk} = \hat{m}^{hk}$. Differentiating (14) with respect to p_s and rearranging now gives the familiar relation

$$(16) \qquad \sum_{s=1}^{4} \mu^{hk}_s \varepsilon^{hk}_{sj} + \mu^{hk}_j = 0.$$

Substituting into (15) from the consumer demand functions (11) gives the result we seek:

$$(17)\qquad \hat{e}^{hk} = \sum_{j=1}^{4} \hat{p}_j \left(\sum_{s=1}^{4} \mu_s^{hk} \varepsilon_{sj}^{hk} + \mu_j^{hk} \right) + \hat{m}^{hk} \sum_{j=1}^{4} \mu_j^{hk} \eta_j^{hk}$$

$$= \hat{m}^{hk}$$

In the next section we calculate changes in poverty and aggregate consumption in terms of changes in real household expenditures. After a brief review of poverty measurement issues we derive equations describing the effects of exogenous technical change shocks on household poverty and economic welfare.

Poverty and Welfare Measures

Poverty Measures

All poverty measures deem a household to be poor if its income or expenditure falls below a given poverty line, z. However, they differ by degree of inequality aversion, i.e. in the weight they assign to distance below z. Foster, Greer and Thorbecke (1984, hereafter FGT) present a class of poverty measures parametric in inequality aversion. These are defined as follows: for any homogeneous group of size N with incomes $Y_1,...,Y_N$ listed in ascending order, define the 'income gap' of the ith household by $g_i = z - y_i$. The income gap is positive for $q \leq N$ households whose income falls below the poverty line, and zero for the rest. The FGT class of poverty measures $P_\alpha(y,z)$ is given by:

$$(18)\qquad P_\alpha(y,z) = \frac{1}{Nz^\alpha} \sum_{i=1}^{q} g_i^\alpha$$

When $\alpha = 0$, P_α reduces to the popular headcount measure $H = q/N$, which records merely the fraction of the population falling below the poverty line and is thus insensitive to the distribution of income among the poor. Higher values of a indicate greater 'poverty aversion': as the value of α increases, P_α satisfies measurement criteria giving increasing weight to the poorest of the poor households. Many empirical poverty studies adopt P_2 as a preferred measure.

FGT poverty measures are additively decomposable across groups in a population. For a population composed of m groups of households[3] with group income vectors $Y^1,..., Y^m$:

[3] Although we use household data in this paper, the properties of P_α measures are not specific to a particular unit of measurement.

(19) $$P_\alpha(y;z) = \sum_{j=1}^{m} \frac{N_j}{N} P_\alpha(y^j, z),$$

where N_j/N is the share of the group j in total population. An increase in poverty in any single group increases the overall poverty measure by an amount weighted by its population share. Table 4 shows our computations of P_0, P_1 and P_2 in the Philippines by household group, based on two alternative poverty lines. The lower line indicates a headcount measure of 33 per cent poverty and the higher line 48 per cent, comparable with other estimates (e.g. Balisacan 1993).

TABLE 4

Philippines: Poverty by Household Group under Alternative Poverty Lines and Poverty Definitions, 1985

Household Group	z = Pesos15,000			z = Pesos 20,000		
	P_0	P_1	P_2	P_0	P_1	P_2
Laborers	0.4168	0.1265	0.0519	0.5950	0.2239	0.1020
S capitalists	0.1506	0.0395	0.0142	0.2875	0.0885	0.0345
M capitalists	0.1534	0.0401	0.0144	0.2781	0.0877	0.0347
Landlords 1	0.1857	0.0631	0.0288	0.2770	0.1062	0.0506
Landlords 2	0.4690	0.1975	0.1052	0.5759	0.2735	0.1526
Farmers 1	0.3282	0.0870	0.0308	0.5455	0.1804	0.0734
Farmers 2	0.5911	0.1950	0.0859	0.7774	0.3172	0.1538
All Households	0.3304	0.1031	0.0437	0.4872	0.1819	0.0834

Source: Computed from NSO 1985.

We now seek an expression for the change in poverty due to changes in household incomes. Holding z fixed and allowing the y^j terms to vary in (19), the proportional change in the FGT poverty measures is:

(20) $$\frac{dP_\alpha(y{:}z)}{P_\alpha} = \hat{P}_\alpha = -\alpha \sum_{i=1}^{q} \mu_i(\alpha,z)\left(\frac{y_i}{g_i}\right)\hat{y}_i, \qquad \alpha > 0$$

where

(21) $$\mu_i(\alpha,z) = \left(\frac{g_i^\alpha}{\sum g_i^\alpha}\right), \qquad g_i > 0$$

The variable $\mu_i(\alpha, z)$ may be described as the a-adjusted poverty gap of household i relative to the aggregate of the α-adjusted poverty gaps of all poor households. It is a function of the parameters α and z, as well as the income of household i. When $\alpha = 1$, μ_i is simply the poverty gap of household i relative to the aggregate poverty gap. Increasing positive values of α yield proportional changes in the poverty measure which accord greater weight to changes in the expenditures of the poorest households.

Welfare Measures

The measurement of poverty is a special case of welfare analysis in which the welfare of each household above the poverty line is assigned a zero weight. In reality, poverty alleviation is only one among many policy targets. It is important, therefore, to consider the effects of technical progress (or any similar change) on the total population. In the context of a more general evaluation of social welfare change, concern with poverty alleviation may be represented by manipulation of the weights assigned to households whose initial income or expenditure places them below the poverty line.

The most commonly employed measure of aggregate economic welfare is real gross national product. This may be computed as the sum over all households of real household income. It is obvious that the computation of *proportional changes* in real GNP by this means gives a relatively higher weighting to proportional changes in the incomes of rich households. Let W be national welfare, a function of the incomes of the N households, $y_1,\ldots,y_N$. Now write the proportional change in aggregate welfare as:

$$\hat{W} = \sum_{i=1}^{N} \omega_i \hat{y}_i , \tag{22}$$

where $\omega_i = (\partial W/\partial y_i)(y_i/W)$, the elasticity of W with respect to y_i, may be interpreted as the welfare weight attached to a unit proportional change in the income of the i th household. Now consider the standard form of GNP measure, Y, the sum of the incomes of the N households. Then $w_i = y_i/Y$. If income is unequally distributed then $\hat{W}$ is dominated by proportional changes in the incomes of initally wealthy households.

As a 'neutral' alternative to income weights, Todaro (1989) suggests the use of the shares of household groups in total population. For each decile of the income distribution, for example, each ω_i would take a value of 1/10. Such a weighting scheme treats equal proportional changes in the welfare of all households as having equal social value. Both this and the income weights measure of national income are considered in our model.

In the spirit of the FGT poverty measures, an alternative set of welfare weights yielding a poverty-oriented welfare measure could be derived directly from the poverty measures themselves, using the household poverty gaps and α as in (21) and (22):

$$\omega_i = \mu_i(\alpha, z)\,. \qquad (\alpha = 1,2) \tag{23}$$

These measures take no account of the welfare of households initially above the poverty line. For increasing values of α they assign greater weight to proportional changes in the incomes of the poorest households. For $\alpha = 1$, the growth weights depend only on the distance by which each poor household falls below the poverty line. These are the weights implied by the poverty measure P_1. The use of weights with $\alpha = 2$ (corresponding to P_2) strengthens the redistributive orientation of the welfare analysis by further taking into account the distribution of income changes among poor households.

Using 1985 income data for deciles of the Philippine population, Figure 2 provides a graphical comparison of the values of welfare weights implied by the standard GNP aggregation, population share weights, and FGT poverty measures P_1 and P_2. The figure illustrates the higher degree of inequality aversion of the P_2 weights relative to those based on P_1.

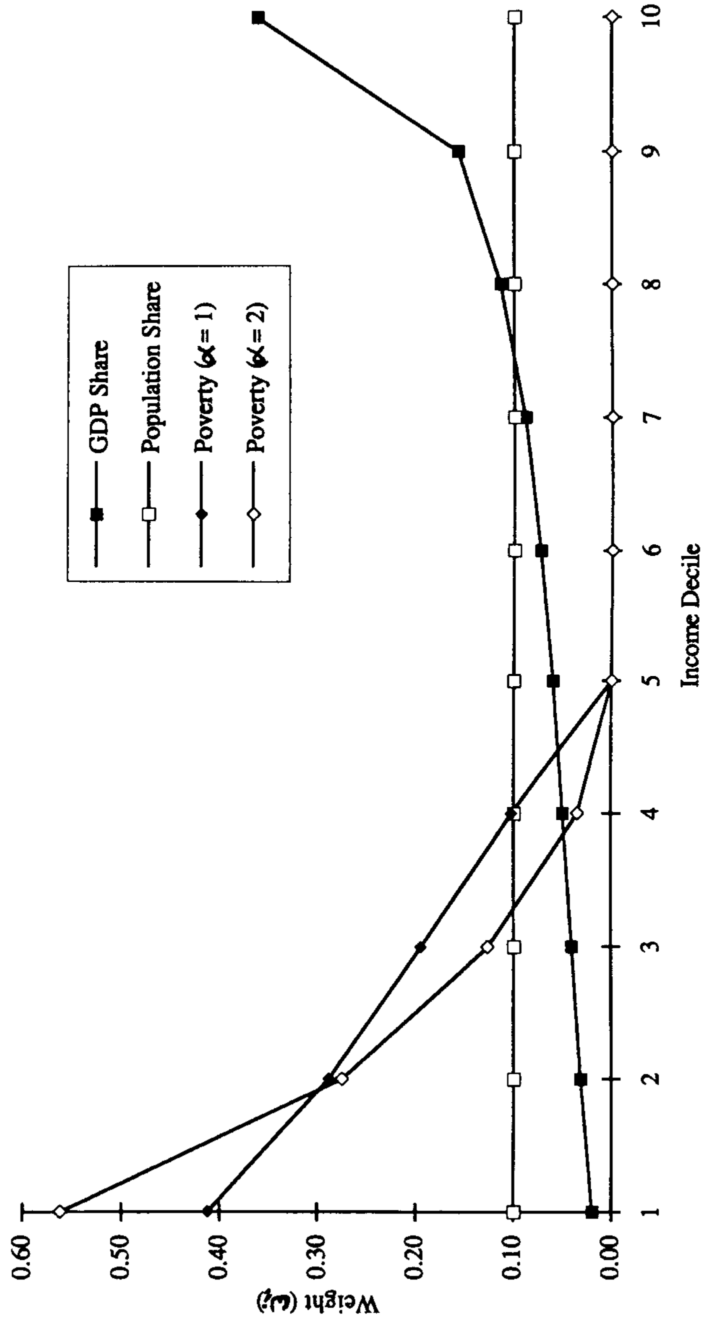
Poverty Impacts of Technical Change

In this section we report the results of technical progress simulation experiments using the model described earlier in the paper, and incorporating the poverty measures set out above. We parameterize the model using mainly synthetic data intended to be broadly representative of the structure of the Philippine economy. These data are presented in Tables 5 to 7.[4] Table 5 shows the characteristics of production and factor use in each sector. Table 6 shows the numerical distribution of the asset ownership pattern of Table 1 along with a breakdown of each household's factor incomes by source. Table 7 shows our assumptions on consumer expenditures. Budget shares of goods consumed are the same for all household groups within each expenditure class, and are assumed to change monotonically across expenditure classes. Thus the household budget share of the non-tradeable good, services, is the same for all factor-owning groups within an expenditure class, and rises monotonically from the lowest to the highest class.[5] Similarly, the budget share of agricultural goods is constant across groups within each expenditure class and declines monotonically across classes. For all households we assume own-price elasticities of demand for agriculture and services of -0.5 and -1.25 respectively;

[4] The use of stylized rather than actual data for production and input use in our model is justified by the high degree of aggregation, which in turn serves our aim of exposing economic mechanisms through which technical change affects poverty and income distribution. However, simulation results obtained using the model are consistent with comparable results from a much less aggregated model (Warr and Coxhead 1993) based entirely on Philippine data and econometrically estimated parameters.

[5] Values of consumer demand parameters draw information from Pante (1979), Lluch, Powell and Williams (1977), and Kravis, Heston and Summers (1983).

FIGURE 2



Source: NSO 1985

cross-price elasticities of these goods are 0.1, and expenditure elasticities are 0.3 and 1.2.

TABLE 5
Production Sector Parameters

	Sector				
	1 (Agriculture 1)	2 (Agriculture 2)	3 (Services)	4 (Manufacturing)	Total
Sector shares in mobile factor demand (λ)					
Labor	0.30	0.20	0.30	0.20	1.00
Capital	0.20	0.05	0.30	0.45	1.00
Sector shares in GNP (γ)					
	0.225	0.141	0.282	0.352	1.00
Factor shares in total cost (θ)					
Labor	0.375	0.400	0.300	0.160	
Capital	0.250	0.100	0.300	0.360	
Irrigated land	0.375	–	–	–	
Non-irrigated land	–	0.500	–	–	
Services capital	–	–	0.400	–	
Mfg. capital	–	–	–	0.480	
Total	1.00	1.00	1.00	1.00	
Allen elasticities of factor substitution (σ)					
	0.5	0.5	0.5	0.5	

Source: Authors' estimates.

TABLE 6

Household Asset Distribution and Factor Income Shares

Household Group	Factor: Labor	Mobile Capital	Sector 1 Land	Sector 2 Land	Sector 3 Capital	Sector 4 Capital	Total
	Contribution to total household income (δ)						
Laborers	1.0	–	–	–	–	–	1.0
S capitalists	–	0.3	–	–	0.7	–	1.0
M capitalists	–	0.3	–	–	–	0.7	1.0
Landlords 1	–	0.5	0.5	–	–	–	1.0
Landlords 2	–	0.4	–	0.6	–	–	1.0
Farmers 1	0.3	0.4	0.3	–	–	–	1.0
Farmers 2	0.4	0.2	–	0.4	–	–	1.0
	Household share in total factor ownership (θ)						
Laborers	0.4	–	–	–	–	–	
S capitalists	–	0.2	–	–	1.0	–	
M capitalists	–	0.5	–	–	–	1.0	
Landlords 1	–	0.1	0.7	–	–	–	
Landlords 2	–	0.1	–	0.7	–	–	
Farmers 1	0.3	0.05	0.3	–	–	–	
Farmers 2	0.3	0.05	–	0.3	–	–	
Total	1.0	1.0	1.0	1.0	1.0	1.0	

Source: See text.

Technical change alters product supply and factor demand directly in the sector to which the shock applies, and indirectly in all sectors through price and quantity adjustments in factor and product markets. The values of these changes are obtained by the requirement that changes in supply equal changes in demand in the markets for labor, capital and the non-tradeable good. Since the model is oriented to the short run, changes in aggregate supplies of both mobile and specific factors are restricted to zero. Changes in the functional distribution of income can thus be read directly from changes in factor prices.

Simulations using the model[6] were conducted with values of technical change parameters estimated from Philippine agricultural data (Coxhead

[6] Simulation software used was Gempack (Codsi and Pearson 1988).

1992), reported in Table 8. The short-run overall rate of technical change in irrigated agriculture (Sector 1 in our model) exceeded that for non-irrigated agriculture (Sector 2) by a factor of about 20 — in fact, the measured rate of technical progress in the latter sector was almost zero. Technical progress in irrigated areas exhibited strongly land-saving and weakly labor-saving biases due to the combined effects of adoption of MVs of rice and agricultural mechanization during the period studied. By contrast, technical change in unirrigated agriculture was approximately neutral with respect to factors.

TABLE 7

Consumers' Expenditure Shares

Expenditure Class[a]	Consumer Good			
	Agriculture[b]	Services	Manuf.	Total
1	0.550	0.166	0.284	1.0
2	0.510	0.168	0.322	1.0
3	0.470	0.176	0.354	1.0
4	0.430	0.192	0.378	1.0
5	0.380	0.224	0.296	1.0
6	0.330	0.259	0.411	1.0
7	0.280	0.302	0.418	1.0
8	0.220	0.358	0.422	1.0
9	0.150	0.412	0.438	1.0
Weighted average	0.314	0.283	0.403	1.0

[a] All household groups in the same expenditure class are assumed to have a common expenditure patttern.
[b] The agricultural good is produced in sectors 1 and 2.

TABLE 8

Estimated Short-run Productivity Growth in Philippine Agriculture, 1960-84, by input and land type (per cent changes)[a]

Land type	Overall rate of technical change	Factoral rates of technical change		
		Land	*Labor*	*Capital*[b]
Irrigated	0.76	1.48	0.63	–0.19
Non-irrigated	0.03	0.10	–0.12	–0.01

[a] Figures represent short-run (approximately annual) rates. Positive (negative) sign indicates factor-saving (using) bias of technical change.
[b] Fertilizer.
Source: Calculated from estimates in Coxhead (1992).

Results Under Open Agricultural Trade

We first consider the properties of the model described earlier in the paper, in which agricultural commodities are freely traded. Table 9 shows the effects of technical change on mobile factor demands, sectoral outputs, and the prices of factors and of the non-tradeable good. Since demand for agricultural output is elastic, output and mobile factor demands rise in sector 1 (irrigated agriculture), where technical change has been rapid.

TABLE 9

Effects of Technical Change Shocks on Production, Factor Demand and Prices (per cent change)[a]

Endogenous Variable	Total Shock
Labor demand	
Agriculture 1	0.75
Agriculture 2	–0.40
Services	–0.15
Manufacturing	–0.51
Capital demand	
Agriculture 1	1.22
Agriculture 2	–0.40
Services	–0.08
Manufacturing	–0.44
Production	
Agriculture 1	1.33
Agriculture 2	–0.20
Services	–0.07
Manufacturing	–0.24
Real mobile factor prices	
Labor	0.53
Capital	0.41
Real specific factor prices	
Agriculture 1	1.18
Agriculture 2	0.50
Services	0.24
Manufacturing	–0.48
Real price of non– tradeables	0.38
GDP	0.17

[a] Values of the estimated rates of technical progress in Table 10.

Technical progress increases the marginal value product of factors employed in irrigated agriculture. This attracts factors away from other sectors not experiencing similar rates of productivity growth, bidding up mobile factor prices. In sector 2, factor price rises caused by the expansion of output in sector 1 increase production costs, but the rate of technical progress in this sector is insufficient to offset the squeeze on profits. Output and returns to land therefore decline. The manufacturing sector also loses from mobile factor price increases, and production in this sector declines by a similar proportion. The sector producing non-tradeables is also affected by input cost increases, but because demand for the non-tradeable is price-inelastic, technical progress in agriculture brings about a *real appreciation* — a rise in the relative price of the non-tradeable good. This increase, combined with the effects of increased spending on non-tradeables out of the new income generated by technical progress, ensures that output in the services sector declines by much less than in the other 'lagging' sectors. The intersectoral transmission of the effects of the technical change shock in agriculture is equivalent to that analysed for the cases of resource discoveries in 'booming sector' models (Corden and Neary 1982; Cassing and Warr 1985).

Table 10 reports changes in household poverty resulting from the effects of the technical change. Results are shown for the two poverty measures P_1 and P_2. The total general equilibrium effects in column 5 show relatively large poverty reductions among laborers and among landlords and farmers owning land in sector 1. Smaller poverty reductions are enjoyed by owners of the factor specific to the services sector. Poverty increases among owners of capital specific to manufacturing and among landlords in agricultural sector 2, not undergoing rapid technical change. Farmers in sector 2 experience almost no change in poverty.

Laborers' gains are derived primarily from wage rises; however, since most laborer households fall near the lower end of the income distribution and therefore spend a smaller fraction of their incomes on the non-tradeable good, their *real* incomes are reduced less by the rise in the price of the non-tradeable than are those of wealthier groups.

Because the technical change shocks occur in relatively labor-intensive sectors of the economy, wages rise relative to mobile capital returns (Table 9). This alleviates poverty among irrigated sector farmer households, whose incomes are derived mainly from wages. Producers in manufacturing are caught between rising input prices and falling relative output prices; poverty among owners of the factor specific to this sector therefore rises. The poverty reduction among owners of factors specific to services is caused by the real appreciation described above.

While these results make intuitive sense, the structure of our model permits a deeper analysis. Our general equilibrium approach exposes the intersectoral, indirect effects of a change (such as technical progress) directly affecting only a subset of sectors in an economy. In Table 10 we demonstrate the operation of intersectoral linkages by separating the observed poverty changes into their components due to factor market adjustments, and changes in the relative prices of non-tradeable and tradeable goods.

TABLE 10

Poverty Changes (per cent) Due to Technical Change Shocks

Household Group	Pop'n Share (%)	Resource Movement (RM) Effect: Factor Markets (1)	Resource Movement (RM) Effect: Real Apprec'n (2)	Resource Movement (RM) Effect: Total RM Effect (3)=(1)+(2)	Spending Effect (4)	General Equilib'm Estimate (5)=(3)+(4)	Partial Equilib'm Estimate [a] (6)
			Poverty Measure = P_1				
Laborers	24.0	–0.68	–0.03	–0.71	–0.05	–0.76	0.06
S capitalists	19.8	0.63	–0.82	–0.19	–0.30	–0.49	–0.71
M capitalists	11.5	0.34	0.11	0.45	0.16	0.61	0.08
Landlords 1	10.7	–1.33	0.07	–1.26	0.10	–1.16	–1.53
Landlords 2	5.4	0.12	0.04	0.16	0.06	0.22	0.03
Farmers 1	12.0	–1.31	0.03	–1.28	0.06	–1.22	–1.12
Farmers 2	16.6	–0.10	0.02	–0.08	0.04	–0.04	0.05
All Households	100.0	–0.31	–0.06	–0.37	–0.10	–0.47	–0.40
			Poverty Measure = P_2				
Laborers	24.0	–0.98	–0.05	–1.03	–0.08	–1.11	0.09
S capitalists	19.8	0.87	–0.61	0.26	–0.95	–0.69	–1.00
M capitalists	11.5	0.49	0.14	0.63	0.23	0.86	0.11
Landlords 1	10.7	–1.82	0.09	–1.73	0.14	–1.59	–2.10
Landlords 2	5.4	0.18	0.05	0.23	0.09	0.32	0.05
Farmers 1	12.0	–1.89	0.05	–1.84	0.08	–1.76	–1.62
Farmers 2	16.6	–0.15	0.00	–0.15	0.09	–0.06	0.07
All Households	100.0	–0.44	–0.09	–0.53	–0.15	–0.68	–0.56

[a] Computed under assumption of constant mobile factor prices.

The direct effect that a particular shock has on factor markets — at constant commodity prices — is found by constraining the change in the price of the non-tradeable good to be zero. The *resource movement effect* is the sum of the factor market adjustments so obtained, and the effects of the shock on the price of the non-tradeable net of the effects of increased consumer spending arising from the shock. This is found by computing the effects of the shock with consumer expenditure elasticities equal to zero. The *spending effect* of the shock — changes due to increased consumer demand from the rise in income — is found by assuming that the shock has no effect on factor demands within the sector to which it applies. It is calculated as the difference between the resource movement effect and the total effect of the shock (Corden and Neary 1982).

Columns 1-5 of Table 10 display the results of this decomposition for the technical change shocks in Table 8. For both poverty measures, factor market adjustments account for about two-thirds (65 per cent) of the total reduction in aggregate poverty, and the total resource movement effect accounts for 78 per cent. The spending effect accounts for the remaining per cent.

The general equilibrium treatment allows factor prices to adjust endogenously in response to technical change shocks. However, most empirical studies of technical change and income distribution in agriculture are more restrictive, typically assuming that intersectorally mobile factors (e.g. capital and labor) are available to agriculture in infinitely elastic supply (e.g. Hayami and Herdt 1977). We describe the use of such a restriction as 'partial equilibrium'. For comparative purposes we present simulated poverty changes incorporating this restriction in column 6 of Table 10. Comparison of columns 5 and 6 reveals that by ignoring factor market effects, a partial equilibrium treatment would somewhat underestimate the extent of overall poverty reduction due to technical progress of the type considered here. More importantly, the partial equilibrium estimates yield a distribution of poverty changes very different from that in the general equilibrium estimates. The former underestimate the extent of poverty reduction among owners of intersectorally mobile factors (especially laborers and small farmers) and overestimate that among owners of factors specific to non-agricultural sectors. The potential distortion in a partial equilibrium analysis is even greater if we consider poverty changes only among the poorest household groups, laborers and farmers in sector 2. The partial equilibrium estimates indicate that technical progress caused poverty in these groups to *increase*, whereas the general equilibrium estimates indicate that it *decreased.*

Table 11 shows measures of the impact of technical progress on aggregate economic welfare as described in equation (22). The total general equilibrium welfare gain varies little across weighting rules, ranging from 0.23 per cent with GNP share weights to 0.27 per cent with poverty weights.

Most of the gains accruing to poor households as a result of technical change and its subsequent spending effects are captured through wage

TABLE 11

Aggregate Welfare Changes (per cent) Due to Technical Change Shocks

Weighting System	Resource Movement (RM) Effect					
	Factor Markets (1)	Real Apprec'n (2)	Total RM Effect (3)=(1)+(2)	Spending Effect (4)	General Equilibrium Estimate (5)=(3)+(4)	Partial Equilibrium Estimate[a] (6)
GNP	0.18	0.02	0.20	0.03	0.23	0.25
Population	0.20	0.02	0.22	0.03	0.25	0.20
P_1	0.20	0.03	0.23	0.04	0.27	0.21
P_2	0.20	0.03	0.23	0.04	0.27	0.21

[a] Computed under the assumption of constant mobile factor prices.

changes.[7] These factor price effects are not captured by partial equilibrium analyses. Consequently, when we compute welfare changes using GNP weights (which assign greater weight to real income changes among wealthy households) the partial equilibrium estimate of the resulting welfare change is larger than the corresponding general equilibrium estimate. For the same reason, when welfare gains are computed using distributionally sensitive poverty weights, partial equilibrium estimates are somewhat smaller than the corresponding general equilibrium estimates. By ignoring factor price effects the partial equilibrium estimates suggest that the more poverty-sensitive are the welfare weights used, the *smaller* is the welfare gain due to technical change; the general equilibrium results show the reverse.

Results Under Agricultural Trade Restrictions

Our analysis so far has maintained the assumption that agricultural prices are set exogenously in world markets. In practice the Philippine government, like many others, has long pursued national self-sufficiency in staple grains. To this end it has awarded monopoly powers over international trade in rice, corn and wheat to a government agency, the National Food Authority (NFA). This agency has been charged with defending a legislated price band for cereals through international transactions as well as through domestic purchases and sales (Intal and Power 1990). However, for budgetary and other reasons the NFA has been unable to defend the price band in times of rapid changes in cereal supply or demand. The main instance of this was the period of rapid rice supply growth due to the spread of green revolution rice technologies in the late 1970s, when domestic prices fell substantially below border prices and the legislated price floor was repeatedly breached (*ibid.*, p.49).[8] This period coincided with a temporary end to rice imports as the country briefly achieved self-sufficiency in rice (IRRI 1991).

Did the international trade restrictions alter the impact of technical progress on poverty and its distribution? We address this question by representing the government's policy in polar form. We recompute the impacts of the technical progress shocks in Table 8, holding trade in

[7] If wages were rigid (as might be the case if there were slack in the labor market) these factor price effects would be zero. Instead, income effects would reach households through increased employment as the technical progress increased labor demand. The effects of employment changes on poverty would depend on the distribution of initial unemployment, and of re-entry to the paid labor force, across households.

[8] Intal and Power (1990, pp.65-73 and Fig. 3.1a) present evidence that for most of the period from 1970 to the late 1980s domestic producer prices of agricultural products closely followed world prices. In rice, the major crop, producer prices approximately matched border prices from 1960 to 1972. The Philippines was shielded from the world commodity price boom of 1972-75, a period in which domestic price controls were 'implemented aggressively' (Intal and Power, p.66). However, in 1976-80, producer prices dropped substantially below border prices; the gap was only closed again after 1981.

agricultural goods fixed and allowing their price to be determined entirely in domestic markets. The results of this experiment are summarized in Tables 12 and 13. Under this 'self-sufficiency' assumption, technical progress causes the price of agricultural output to fall substantially, by 1.5 per cent. The price fall sets off a Stolper-Samuelson pattern of reductions in returns to factors used relatively intensively in agricultural sectors, and increases in returns to factors used intensively in non-agriculture — notably in manufacturing, the sector in which relative output prices increase.

TABLE 12

Effects of Technical Change Shocks on Production, Factor Demand and Prices, with Agricultural Trade Restriction (per cent change)[a]

Endogenous Variable	Total Shock
Labor demand	
Agriculture 1	0.21
Agriculture 2	–0.71
Services	–0.07
Manufacturing	0.51
Capital demand	
Agriculture 1	0.33
Agriculture 2	–1.05
Services	–0.37
Manufacturing	0.22
Production	
Agriculture 1	0.90
Agriculture 2	–0.38
Services	–0.13
Manufacturing	0.16
Real mobile factor prices	
Labor	–0.69
Capital	–0.14
Real specific factor prices	
Agriculture 1	–1.13
Agriculture 2	–2.33
Services	–0.85
Manufacturing	0.32
Real price of agricultural goods	–1.46
Real price of services	–0.58
GDP	0.17

[a] Values of the estimated rates of technical change in Table 8.

TABLE 13

Poverty Changes (per cent) Due to Technical Change Shocks with Agricultural Trade Restrictions

Household Group	Poverty Measure	
	P_1	P_2
Laborers	–0.14	–0.25
S capitalists	–0.31	–0.49
M capitalists	–2.06	–2.95
Landlords 1	–0.25	–0.40
Landlords 2	0.71	0.97
Farmers 1	–0.36	0.57
Farmers 2	0.64	0.89
All households	–0.26	–0.41

The fall in agricultural prices benefits all households as consumers, but is insufficient to offset the factor income declines of groups who derive most of their incomes from ownership of low-quality agricultural land. Accordingly, poverty among these groups increases. Comparing Tables 10 and 13, the overall poverty decline produced by the technical progress shock is substantially greater when agricultural trade is unrestricted at a constant world price.

Compared with the tradeable food case, technical progress in agriculture when food trade is restricted generates large changes in commodity prices. These in turn induce substantial variation in real income gains within and across household groups. Table 14 reports real income changes for each household income group and expenditure class. As before, variation within a column reflects different rates of change in money incomes, while variation within a row reflects different rates of change in expenditure class-specific consumer price indices. The table shows that the green revolution in the Philippines had two distinct effects on the distribution of real incomes. Among poor households, owners of low-quality agricultural land in sector 2 suffered absolute real income declines. Since these are among the poorest of all household groups in our analysis, the green revolution worsened income distribution among poor households. Among all households, however, the green revolution had positive distributional effects because the price of food, the major consumption good of the poor, declined relative to the prices of other goods.

The results of this experiment suggest that by defending a largely political goal — self-sufficiency in cereals — the Philippine government may have foregone rural poverty reduction opportunities presented by the

TABLE 14

Household Real Income Changes (per cent)
Due to Technical Change Shocks with Agricultural Trade Restrictions[a]

Household Group	Expenditure Class 1	2	3	4	5	6	7	8	9
Laborers	2.03	1.46	0.92	0.43	–0.11	–0.63	–1.11	–1.66	–2.37
S capitalists	2.71	2.14	1.60	1.11	0.57	0.05	–0.43	–0.98	–1.69
M capitalists	10.85	10.28	9.74	9.25	8.71	8.19	7.71	7.16	6.45
Landlords 1	2.75	2.17	1.64	1.15	0.61	0.08	–0.40	–0.95	–1.65
Landlords 2	–5.43	–6.00	–6.54	–7.03	–7.57	–8.10	–8.57	–9.12	–9.83
Farmers 1	3.04	2.47	1.93	1.44	0.90	0.38	–0.10	–0.65	–1.36
Farmers 2	–3.33	–3.90	–4.44	–4.93	–5.47	–5.99	–6.47	–7.02	–7.73

[a] Household group-specific money incomes deflated by expenditure class-specific consumer price indices.
For details of household-specific factor income and expenditure patterns see Tables 6 and 7.

green revolution. Clearly, self-sufficiency policies conferred benefits on urban populations and penalized rural groups: the poverty increases recorded by mainly rural household groups in our experiment are consistent with data showing that the urban-rural real income ratio increased throughout the peak green revolution years, while aggregate poverty incidence remained roughly constant.

Conclusions And Policy Implications.

This paper has analyzed the general equilibrium effects that technical change in agriculture has on income distribution, poverty and economic welfare within a simple open economy. Our analysis utilizes a small, deliberately stylized general equilibrium model which distinguishes between irrigated and non-irrigated agricultural production, between traded and non-traded goods and between households of varying expenditure and income-earning characteristics. We use this model to measure poverty changes under a variety of distributional weighting rules.

Our analysis suggests that estimates of the effects that technical progress has on poverty and economic welfare are far more sensitive to the structural features of the general equilibrium framework in which the analysis is conducted than to the distributional sensitivity of the particular poverty or welfare measure that is chosen. Our analysis also confirms that the resulting changes in poverty and welfare are due substantially to the distributional implications of changes in factor prices — in our experiments, more so than to changes in commodity prices. Partial equilibrium analyses of poverty which focus exclusively on commodity price changes, with factor prices held constant, will thus be likely to miss an important part, perhaps the central point, of the true story.

Nevertheless, policies which do affect the behavior of commodity prices have important implications for poverty and for its relationship to technical change. Some of these policies, such as food price ceilings, are instruments aimed directly at the alleviation of poverty among certain groups, whereas others, such as trade restrictions, may be seen by policymakers as having little connection with the incidence of poverty. By exposing both the direct and indirect effects of price changes on real household expenditures, an analytical approach of the kind we have presented can assist in evaluating not only the efficacy of explicit poverty alleviation programs, but also in recognizing the poverty linkages of interventions which are not related in an obvious way to poverty incidence.[9] Moreover, this analytical framework can shed light on a particularly vexing problem, that of the imperfect targeting of poverty alleviation instruments. This well-known problem stems from the fact that the benefits of most poverty alleviation measures are not captured only by poor families. Food subsidies, for example, reduce prices for all consumers, including the rich. Targeting through means tests or other measures is

[9] Note that in our model, Hicks-neutral technical progress in a sector has effects equivalent to those of a rise in the price of the commodity produced in that sector.

commonly prohibitively costly and/or open to corruption. A carefully specified general equilibrium model can help provide *ex ante* indications as to which policy instruments might best target specific groups.

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