Peter G. Warr and Ian A. Coxhead[*]

THE DISTRIBUTIONAL IMPACT OF TECHNICAL CHANGE IN PHILIPPINE AGRICULTURE: A GENERAL EQUILIBRIUM ANALYSIS[†]

Studies of the role of the agricultural sector in economic development have emphasized the importance of the rate and nature of technical progress in agricultural production (Falcon, 1970; Johnston and Mellor, 1961; Timmer, 1988). The characteristics of technical change in agriculture have been recognized as critical for the overall direction of the development process, not least for its income distributional characteristics (Johnston, 1972; Gotsch, 1972; Hayami and Ruttan, 1985).

This paper takes previous empirical estimates of the rates and factor biases of technical changes occurring in Philippine agriculture over the interval 1960 to 1984 and explores their distributional implications within the Philippines. The exercise utilizes a recently constructed 41-sector, 50-commodity, empirically based applied general equilibrium (AGE) model of the Philippine economy (Warr, 1994b).

Between 1960 and 1984, the average annual rate of growth of real national output per head of population in the Philippines was 2.8 percent. The results of our analysis imply that technical change in agriculture alone contributed almost one third of this growth. Moreover, the benefits of this technical

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change were concentrated in the poorest groups of the Philippine population. While all quintile groups of the Philippine income distribution gained in real terms from the technical change, the poorest groups benefited proportionately the most.

Our results confirm the power of general equilibrium analyses for analyzing complex economic phenomena of this kind—where the interaction between factor markets, product markets, and the expenditure characteristics of different household groups are critical. While the conventional wisdom has been that technical change in agriculture typically exacerbates income inequalities, these conclusions have been based, almost entirely, on partial equilibrium analyses. Our results show that these conclusions can be reversed once the indirect effects of technical change—those operating through the prices of the goods consumed by the poor—are incorporated into the analysis.

POLICY BACKGROUND

Half of the Philippines' workforce is directly employed in farm work and a further one-fifth in rural non-farm employment related to agriculture. The total labor force is currently growing at over 2.5 percent per year. It is thus obvious that continued agricultural growth is central for the alleviation of poverty and for improved levels of living for the entire population. Since agricultural exports constitute 40 percent of the value of all exports, increased agricultural productivity is also vital for improvement of the Philippines' international trading position—a critical matter, in view of the Philippines' high level of foreign indebtedness.

A long-term decline in the per capita availability of arable land has left technical progress at the forefront among sources of agricultural growth in the Philippines. Productivity improvements have been the main sources of growth in Philippine agriculture for more than two decades, and their importance has continued to increase since the beginning of the 1960s.[1] Opportunities for the opening of new lands for cultivation or for increasing the area under irrigation are becoming increasingly limited. It is therefore likely that technical progress will continue to drive agricultural growth for the foreseeable future. The rate and nature of this technical progress thus will largely determine the agricultural sector's contribution to the growth of national income, employment, and exports, as well as to the reduction of poverty.

Poverty in the Philippines is disproportionately concentrated in rural areas, a fact that the Philippines shares with most developing countries, including its Southeast Asian neighbors (Table 1). In 1990 the rural population

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[1] Between 1956 and 1984 total factor productivity in Philippine agriculture grew at an annual average rate of 1.9 percent (Evenson and Sardido, 1986). Sustained productivity growth is evident even if the Green Revolution years of 1965 to 1974 are excluded from the factor productivity calculation (ibid., Table 1).

Table 1.—Growth and Poverty Trends in Southeast Asia

Country	Annual per capita real GDP growth, 1965-86 *(percent)*	Poverty incidence *(percent)*			
		Year	Rural	Urban	Total
Indonesia	4.6	1976	40.4	38.8	40.1
		1978	33.9	30.8	33.3
		1980	28.4	29.0	28.6
		1981	26.5	28.1	26.8
		1984	21.2	23.1	21.6
Malaysia	4.3	1957-58	59.6	29.7	51.2
		1970	58.7	21.3	49.3
		1979-80	37.4	12.6	29.0
		1983	41.6	11.1	30.3
Philippines[a]	1.9	1961	80.2	65.0	75.0
		1965	71.1	57.4	67.1
		1971	66.1	51.3	61.6
		1985	63.3	52.0	59.7
		1988	54.1	40.0	50.0
Thailand[b]	4.0	1962-63	61.0	38.0	57.0
		1968-69	45.0	25.0	42.0
		1975-76	37.0	22.0	33.0
		1981	34.7	21.1	31.3
		1988	30.6	8.6	25.2

Sources: GNP growth data from World Bank, *World Development Report, 1988*, Oxford University Press, New York. 1988. Poverty data from Rao (1988), except:

[a] Philippine data from Balisacan (1993);

[b] Thai data from Suganya and Somchai (1988), except for 1988, which is from Krongkaew (1993)

of the Philippines, as a proportion of its total population was 57 percent. But the numbers of rural poor as a proportion of the total number in poverty was 67 percent.[2] The principal sources of income of the poorest segments of the Philippine population of course include unskilled labor, but also agricultural land. Table 2 and Chart 1 summarize recent data on the size distribution of income for seven socio-economic groups, defined in Table 2. The central point

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[2] See World Bank (1992, Table 31) and World Bank (1990, Table 2.2, p.31). The corresponding proportions for neighboring Southeast Asian nations were: Indonesia, 31 and 91percent; Malaysia, 43 and 80 percent; and Thailand, 23 and 80 percent, respectively.

Table 2.– Philippines: Population Distribution by Socio-Economic Group and Income Class, 1985

Household group	Income class (Thousands of pesos per annum, 1985 prices)									All income classes	Mean income (pesos)
	Under 6.0	6.0-9.9	10.0-14.9	15.0-19.9	20.0-29.9	30.0-39.9	40.0-59.9	60.0-99.9	100 and over		
	Relative frequency (percent households)										
Laborers[a]	0.95	3.49	5.57	4.28	4.90	2.46	1.65	0.61	0.10	24.01	21,931
Capitalists-S[b]	0.15	0.85	1.97	2.70	4.52	3.00	3.26	2.10	1.20	19.75	41,961
Capitalists-M[c]	0.09	0.50	1.18	1.44	2.62	1.95	1.91	1.20	0.65	11.55	41,451
Landlords-I[d]	0.32	0.70	0.96	0.97	1.65	1.26	2.02	1.63	1.13	10.65	51,513
Landlords-N[e]	0.83	0.85	0.87	0.58	0.72	0.43	0.49	0.35	0.31	5.43	31,621
Farmers-I[f]	0.14	1.27	2.51	2.60	2.91	1.25	0.89	0.30	0.08	11.96	23,644
Farmers-N[g]	1.31	3.63	4.89	3.10	2.38	0.70	0.41	0.18	0.04	16.65	16,475
All households	3.79	11.30	17.96	15.68	19.70	11.05	10.63	6.38	3.52	100	31,114

Source: National Census and Statistics Office, Family Income and Expenditure Survey, 1985, Manila.
Notes:

[a] Laborer households are defined as those whose primary sources of income are agricultural wages and salaries, rural non-agricultural wages, and salaries and net receipts from family sustenance activities.

[b] Service sector capitalist households are those whose main sources of income are urban non-agricultural wages and salaries and non-agricultural entrepreneurial activities like wholesale and retail, community, social, recreational and personal services, transportation, storage and communication services, and construction.

[c] Manufacturing sector capitalist households are those whose main sources of income are urban non-agricultural wages and salaries and non-agricultural entrepreneurial activities such as manufacturing, mining and quarrying, and other entrepreneurialactivities.

[d] Landlords – irrigated areas householdsare those whose main sources of income are those sources of income other than ages and salaries, entrepreneurial activities and net receipts from family sustenance in NCR and regions I - IV and XI.

[e] Landlords – non-irrigated areas are those whose main sources of income are those sources of income other than wages and salaries, entrepreneurial activities and net receipts from family sustenance in regions V - X and X.

[f] Small farmers – irrigated areas are those whose main sources of income are agricultural entrepreneurial activities in NCR and regions I - IV and XI.

[g] Small farmers – non-irrigated areas are those whose main sources of income are agricultural entrepreneurial activities in regions V - X and XII.

Chart 1.– Philippines: Distribution of Households
by Income Class, 1985
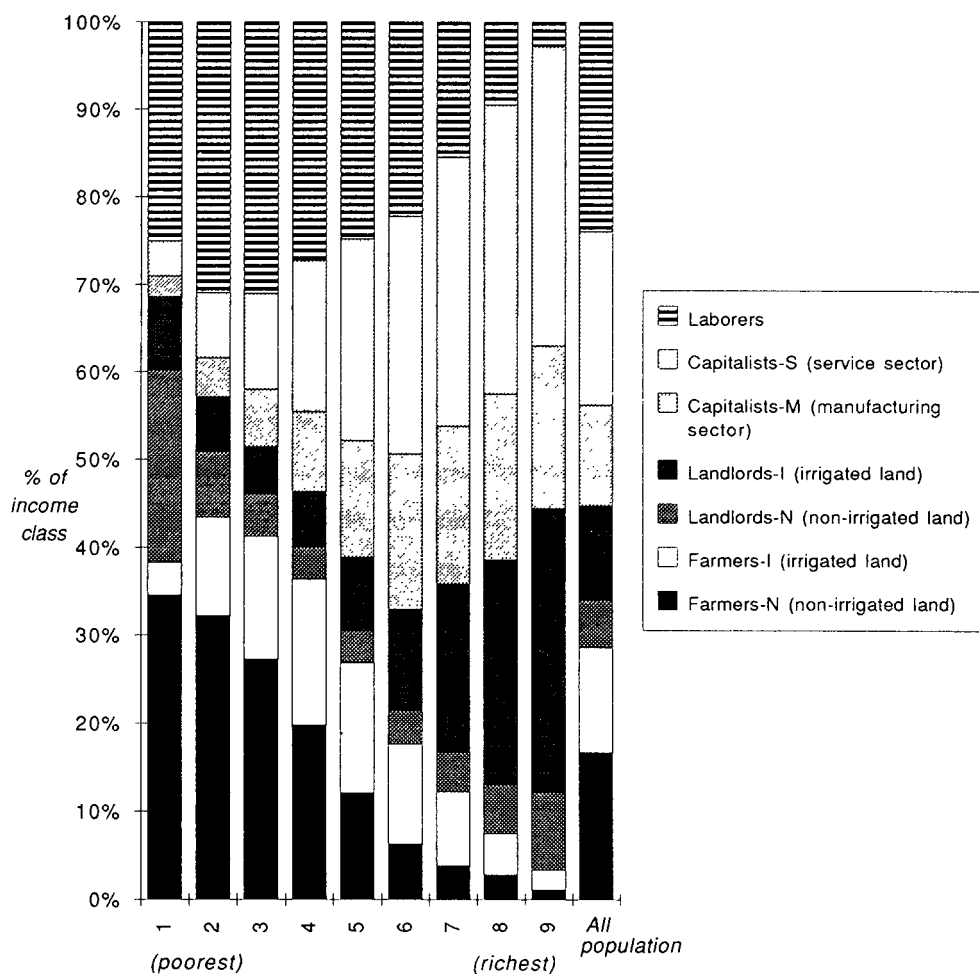
Source: Table 2.
Note: Income classes and household groups are defined as in Table 2.

can be made by focusing on Chart 1. The poorest groups—income class 1 is the poorest and 9 is the richest—include not only a high proportion of laborers, but also a surprisingly high proportion of land-owners. This is especially true of the owners of non-irrigated agricultural land (denoted "Farmers-N" and "Landlords-N" in Table 2 and Chart 1). It would be wrong to assume that even the poorest income groups derive income solely from their labor. Many own agricultural land as well.

The stated economic priorities of the Ramos government of the Philippines, and before it the Aquino government, have placed the greatest emphasis on improved income distribution and accelerated growth (in that order). As a major sponsor of agricultural research and investment in rural infrastructure, the Philippine government thus wishes to be able to evaluate the effects that technical progress may have on economic growth and the distribution of income. Policy makers, or those advising them, therefore need to know the likely effects that technical progress and policies influencing the adoption of technological innovations will have on the real incomes of owners of agricultural inputs—especially primary factor inputs, such as land and labor, but also non-factor intermediate inputs, such as fertilizer and machinery—as well as their effects on the structure of the economy, trade flows, and key macroeconomic indicators.

ANALYTICAL BACKGROUND

The distributional effects of technical change are complex. Technical progress in agriculture increases the productivity of factors used in that sector relative to their productivity elsewhere, *ceteris paribus*. At constant commodity and factor prices, this increases agricultural output and incomes from ownership of agricultural resources—although prices are not expected to remain constant in such circumstances.

New technologies do not merely increase overall productivity. In general, they also lead to differential changes in the productivity of the various factors of production. When adopted in response to changing relative input prices, for example, technical changes typically incorporate biases directed toward raising the productivity of scarce or costly inputs faster than that of more abundant inputs (Hayami and Ruttan, 1985). The technical advance represented by the Green Revolution in rice, for example, is generally thought to have been strongly biased toward saving land relative to other inputs—by increasing yields as well as by making possible more crops per hectare per year.

The existence of factor biases strengthens the likelihood that technical change will alter income distribution within agriculture as well as between agriculture and the rest of the economy. These factor biases inherent in technical change will in turn affect the returns to factors of production in a non-neutral manner. Income distribution thus will be affected in ways that depend on the pattern of factor ownership as well as on changes in factor returns.

The analytical relationship between technical change and income distrib-

ution is complicated further by the fact that technical change can also be expected to alter commodity prices. The expanded supply of agricultural products such as food will normally affect their prices relative to those of non-agricultural products. The nominal prices of agricultural goods may not change, but their relative prices almost certainly will. Even if the agricultural products concerned are traded internationally at fixed international prices, the income effects of expanded agricultural production will induce increased demand for non-traded goods and services, causing their prices to rise relative to those of agricultural goods. These commodity price changes will in turn affect the economic welfare of households in ways that depend on their expenditure patterns.

In short, the income distributional effects of technical change in agriculture, or any other major sector, are not straightforward, nor easily assessed. Their analysis requires use of the most advanced research tools available for the purpose. A general equilibrium approach is required because of the overall size of agriculture, the importance of its links to the rest of the economy, and the complexity of the underlying economic relationships. Agriculture is the largest single sector in the Philippine economy. Its links to other sectors are very important—most notably those operating through the labor market and through markets for staple foods such as rice and corn. In addition, much of the economy's industrial capacity lies in the processing of agricultural products, either for sale in domestic markets or for export. The effects of technical progress are thus transmitted to other sectors through changes in factor and commodity prices and supplies.

PREVIOUS STUDIES

It is apparent that for technical progress to be analyzed in more than a cursory manner requires a substantial commitment of data and human resources. Resource constraints have required most analyses of the issue to date to adopt one of two approaches. They have examined either very broad technical change issues in a general equilibrium context, or specific technical change issues within a strictly partial equilibrium framework.

Analyses of the first type typically assume technical progress to be factor-neutral. While convenient for some analytical purposes, this simplification ignores important empirical phenomena. For example, it was the apparent land-saving, labor-using characteristics of Green Revolution biotechnical innovations that spawned much of the debate over the impact that new rice technologies would have on the distribution of rural incomes. Empirical estimates of the rates and biases of technical progress in Philippine agriculture confirm the importance of strong factor biases. They suggest that technical progress has been strongly land-saving relative to labor and has increased the use of non-factor inputs (machinery and fertilizer), relative to factor inputs. Moreover, the average annual rate of productivity growth of about two percent disguises the fact that technical progress in Philippine agriculture has occurred

at greatly different overall rates between irrigated and non-irrigated areas (Table 3).

The empirical estimation results in Table 3 indicate that technical change in Philippine agriculture has been concentrated in irrigated areas and has been strongly land-saving and fertilizer-using. Within non-irrigated areas the overall rate has been very low, and while it has also been land-saving and fertilizer-using, the estimated factor biases with respect to labor run in opposite directions in the irrigated and non-irrigated environments.

Table 3: Estimated Short-Run Productivity Growth
in Philippine Agriculture, By Input and Land Type, 1969-84*
(Percent change per year)

Land type	Overall rate of technical change	Factoral rates of technical change		
		Land	Labor	Fertilizer
Irrigated	7.645	14.826	6.265	-1.911
Non-irrigated	0.267	1.031	-1.164	-0.019

Source: Calculated from estimates in Coxhead (1992), Table 5.
* Figures represent short-run (approximately annual) rates.

A number of partial equilibrium models have been developed that incorporate some or all of these departures from factor-neutral, sector-wide technical progress (Hayami and Herdt 1977; Ahammed and Herdt 1983). These partial equilibrium models have been useful in clarifying aspects of the linkages between agricultural technology, production, and incomes, but other limitations in their scope, in particular their constant factor price assumptions, restrict their usefulness as tools for policy formation.

By their nature, partial equilibrium models rely on restrictive assumptions about the intersectoral impacts of agricultural growth—even the effects on one agricultural subsector of productivity growth in another. To the extent that changes in factor prices play an important role in the economic adjustments that follow from technical change, partial equilibrium analyses will necessarily ignore an important aspect of the phenomenon of interest.

An important study of technical change in Philippine agriculture by Bautista (1986) measured the effects of exogenous, factor-neutral agricultural productivity increases in a ten-sector AGE model with three sectors producing agricultural goods and a fourth producing processed agricultural products. The model traced the price effects of these stylized factor-neutral technical change shocks—moderated by government transfers and taxes—through to the distribution of income between rural and urban households.

Coxhead and Warr (1991) presented a stylized AGE model explicitly designed for general equilibrium analysis of technical change issues in

Philippine agriculture. The treatment of technical change built upon a framework for the analytical representation of technical change developed by Quizon and Binswanger (1983). This model permitted simulation of a wide variety of factor biases and rates of technical change as well as regional variation in the rate of agricultural productivity growth. This four-sector model (including two agricultural sectors) was deliberately simplified in its characterization of the supply side of the Philippine economy. It generated income distributional results for seven stylized household groups, distinguished by factor endowments as well as by consumption patterns. Another version of this model (Coxhead and Warr, 1992), using the same economic structure and technical progress specifications, further disaggregated the household sector, by income class as well as by income source and expenditure pattern.

The APEX model greatly extends this smaller model's flexibility in dealing with technical change. It incorporates a considerably more disaggregated and detailed representation of the Philippine economy and thereby overcomes some of the most important limitations inherent in the structural and technical specifications of earlier models. APEX also incorporates the results of a large econometric research program directed toward estimating the economic behavioral parameters underlying the model.

THE APEX MODEL

The APEX model, including its structure, its data base, and its behavioral parameters, is documented in full in the technical papers contained in Warr (1994b). For the purposes of the present discussion, its general features, treatment of factors of production, and the special characteristics of its agricultural sector will be described.

General Features

APEX is a conventional, real, micro-theoretic general equilibrium model of the Philippine economy, designed primarily to address micro-economic policy issues for that country. It belongs to the class of general equilibrium models that are linear in proportional changes, sometimes referred to as Johansen models. APEX shares many structural features with the highly influential ORANI general equilibrium model of the Australian economy (Dixon et al., 1982), but these features have been adapted in light of the realities of the Philippine economy. These structural differences are especially important in the treatment of agriculture. The behavioral parameters of the model and its Social Accounting Matrix data base are all estimated from Philippine data.[3]

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[3] These features described are described in full in the papers appearing in Warr (1994b). The key papers are: on the model's structure (Clarete and Warr, 1994); on the data base (Clarete and Cruz, 1994); on the estimation of the behav-

The model contains 50 producer goods and services produced by some 41 industries. Three of these industries are multi-output regional agricultural industries, each jointly producing 12 agricultural producer goods. These agricultural industries are each located in one of the three principal geographic regions of the country—Luzon, Visayas, and Mindanao. Each region produces an identical set of products consisting of 12 agricultural crop and livestock commodities, in proportions that vary across the three regions and depend on relative commodity prices. The elasticities of product transformation governing these supply responses have been estimated econometrically for each of the three regions and therefore reflect differences in regional production conditions. Each of the remaining 38 non-agricultural industries of the model produces an individual non-agricultural producer good or service, making a total of 50 commodities represented. The various industries of the model are classified as either export-oriented or import-competing. The criterion used to classify these industries is the ratio of an industry's imports to its exports. If this ratio exceeds 1.5, then the industry is regarded as producing an importable. The observed exports of such an industry are treated as exogenous in the model. If the import/export ratio is less than 0.5, then the industry is deemed to be export-oriented. For ratios between 0.5 and 1.5, additional relevant information is used in classifying the industry.

Factors of Production

Three primary factors are mobile among the various non-agricultural industries of the model: variable capital, skilled labor, and unskilled labor. Variable capital includes non-agricultural land and structures that are not necessarily devoted to any particular production activity, such as buildings and related fixed structures. When relative prices change, it is possible for owners of such assets to rent them out to producers facing more profitable circumstances.

Unskilled labor is also freely mobile between the non-agricultural and agricultural parts of the economy, but skilled labor and variable capital are not used in agriculture. Thus, skilled labor and variable capital are mobile only among the non-agricultural industries of the model. Skilled labor is defined as those in the work force who are capable of performing tasks requiring more than a specified level of work experience, training, or both. While skilled labor presumably can perform unskilled tasks, the model treats these two kinds of labor as distinct but partially substitutable factors of production.

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ioral parameters of its agricultural component (Warr, 1994a); on estimation of the non-agricultural parameters (Mendoza and Warr, 1994); on estimation of its consumer demand system (Balisacan, 1994); and on estimation of its Armington elasticities of substitution between imported and domestically produced commodities (Kapuscinski and Warr, 1994).

Econometric estimates of the elasticities of substitution between them are reported in Mendoza and Warr (1994).

Besides these variable factors, there are two sets of fixed primary factors: agricultural land and sector-specific capital. Agricultural land is naturally specific to each of the regional agricultural industries of the model. Nevertheless, changes in the output mix within each of the multi-product regional agricultural industries, in response to changing commodity prices, imply that agricultural land may be reallocated among the twelve agricultural outputs of the model. Thus, while land in each region is fixed in total supply, and cannot be allocated to agricultural crops in other regions, it is mobile among crops within its region.

Region and sector-specific capital consists of physical capital assets devoted to a particular line of production activity. There are 41 of these sector-specific factors, one for each of the three agricultural regions and one for each of the 38 non-agricultural industries. Changes in relative prices do not cause any reallocation of such capital inputs in the short run, as a movement to other sectors is assumed to require sufficient re-tooling costs as to render such reallocations economically infeasible.

In a long run setting, the amounts available of each of these region and sector-specific capital resources would adjust as a result of the investments made in each time period of the model. APEX does not allocate its level of fixed capital formation in a given time period into specific industries, because it is essentially a short-run model. The length of run implicit in the model's comparative static adjustment processes should be thought of as being between two and four years.

The Agricultural Sectors

The structure of agricultural production in each of the three regions conforms to the strong assumption of input-output separability. Chart 2 summarizes this feature. In each region, factors of production are employed to produce composite regional agricultural output. The proportions in which factors of production are employed depend on relative factor prices. This composite output then generates the outputs of the various commodities. The key implication is that for a given level of composite output, so determined, the proportions in which the factors of production are used does not affect the proportions in which the various commodity outputs can be produced. The input-output separability assumption may or may not be a good characterization of the joint production processes occurring in Philippine agriculture, but the data available for econometric estimation made this assumption necessary.[4] Time series factor employment data are available for Philippine agriculture only at an aggregate level, and not at the level of individual agricultural

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[4] These issues are discussed in detail in Warr (1994a).

industries or regions.[5]

A further assumption of the model structure is that the joint production of commodities occurs at two levels. At the top level, composite regional output produces the outputs of seven regional sub-industries. Five of these correspond to "single-product" sub-industries: irrigated paddy, coconuts, sugarcane, bananas and other fruits, and other commercial crops (mainly tobacco). The two others are multi-product sub-industries within which a high degree of jointness of production is found. They are called "rainfed aggregate," and "smallholder aggregate" and they produce the commodities indicated in Chart 2.

Chart 2.—APEX: Agricultural Production in Each Region
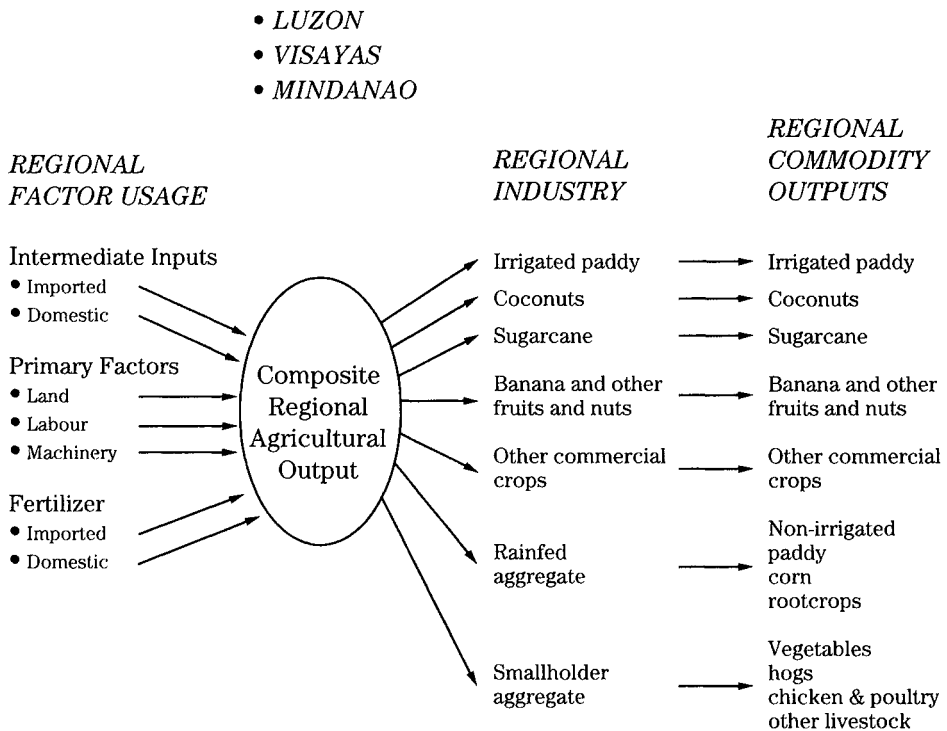
- *LUZON*
- *VISAYAS*
- *MINDANAO*

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Statistical considerations required this degree of nesting of commodities, because of degrees of freedom problems in the estimation process, but the characteristics of Philippine agriculture governed the choice of the particular nesting described above. In spite of the above structural compromises, made necessary by data constraints, comparison with the studies surveyed by Bantilan (1989) shows that the authors' estimates are based on the least restrictive econometric model of the aggregate characteristics of Philippine agriculture presently in existence. Intuitively, the choice of aggregates is consistent with well-known patterns of resource allocation in Philippine agriculture. Farmers in rainfed areas do not monocrop, but allocate land within the farm and the year to different crops. This contrasts with the allocation of irrigated land almost exclusively to monocrop cultivation.

TECHNICAL CHANGE EXPERIMENTS

The simulation experiments using the APEX model are described here. The experiments take the estimated rates of technical change from Table 3 and apply them to APEX. The aim is to determine the economic impact that these observed rates of technical change have had within the Philippine economy, *holding all other exogenous factors constant.* This is the principal value of general equilibrium models like APEX. They can handle controlled experiments, changing one exogenous variable at a time, or any combination of them, holding all other exogenous variables constant. The model was solved using the GEMPACK simulation package, designed for use with linearized models (Codsi, Pearson and Wilcoxen, 1991).

The results should be interpreted as indicating the estimated economic effects of changes in the technical change parameters of the model, based on the empirically measured rates and biases of technical change in Philippine agriculture described in Table 3. Results from this experiment are then used to evaluate the effects that technical progress in agriculture has on economic structure, agriculture's terms of trade with the rest of the economy, key consumer and producer goods prices, income distribution and macroeconomic indicators such as the current account and public sector deficits.

A feature of the experiment is that the above technical change exercise is performed separately for each of the three agricultural regions indicated above—Luzon, Visayas, and Mindanao. The relative importance of irrigated and non-irrigated agricultural production differs greatly among these three regions. The percentage share of irrigated rice in the total value of agricultural output in each of these regions, in 1989 was: Luzon, 34.7; Visayas, 13.4; and Mindanao, 20.9. Since estimated rates of technical change have differed greatly between irrigated and non-irrigated areas (Table 3), there is reason to expect that the overall rates of technical change will have differed correspondingly across the three regions.

Our technical change experiment is based on the assumption that the factoral rates of technical change in *irrigated* rice production (essentially syn-

onymous with irrigated agriculture) are the same in all three regions. A corresponding assumption is made for *non-irrigated* agricultural production (which includes non-irrigated rice). The implications of this assumption for the overall factoral rates of technical change in each region are shown in Table 4. The factoral rates shown in Table 4 were the shocks applied to APEX in the experiment reported below. The overall rates of technical change shown in the table are the cost share weighted sums of the factoral rates.

Table 4.—Regional Rates of Technical Change*

Region	Overall rate of technical change	Factoral rates relative to overall rate		
		Land	Labor	Fertilizer
Luzon	2.831	5.493	1.429	-0.672
Visayas	1.259	2.875	0.122	0.272
Mindanao	1.812	3.908	0.399	-0.713

Source: Calculated from Table 3 and Agricultural Census data on the regional distribution of agricultural production.
* Units as in Table 3.

To perform an experiment with a general equilibrium model like APEX, a macroeconomic closure must be specified, and because the simulation results can be affected by the choice of closure, it is necessary that the main features of the closure be stated. The behavioral parameters and data base were as described in Warr (1994b). All domestic prices, output quantities and consumption quantities were endogenous. The international prices of all exported and imported commodities were fixed exogenously, reflecting the assumption that the Philippines is a price taker in international markets. Trade balance was imposed exogenously and household savings were held fixed in real terms. These features imply that the full economic effects of technical change will be reflected in resulting changes in the levels of household expenditure and thus that their income distributional implications are captured fully within the single-period scope of the analysis. The nominal exchange rate was also fixed exogenously. Its role within the model is to determine the domestic nominal price level. Since there is no monetary sector, the nominal exchange rate plays no role in the achievement of trade balance; that is accomplished by endogenous adjustments in the "real exchange rate"—the ratio of traded to non-traded goods prices.

RESULTS: TECHNICAL CHANGE AND INCOME DISTRIBUTION

A summary of macroeconomic results is provided in Appendix 1. The discussion here will concentrate on one particular aspect of the results—the estimated effects that technical change in agriculture has on household income

distribution. Because some parts of the APEX data base remained under development at the time of these simulations, the details of the results must be considered preliminary.

Table 5 shows, in the first column, the change in money (nominal) household disposable incomes. Household 1 corresponds to the poorest quintile of the income distribution and household 5 to the richest quintile. The second column shows these results deflated by the change in the aggregate consumer price index (which declines in the experiment by 0.4 percent).

The results indicate that both (nominal) disposable incomes, and these changes deflated by the aggregate consumer price index, rise for all households. All households gain from the technical change, when their "real" incomes are measured in this conventional way. However, these results suggest that poor households gain proportionately the least, and the richest gain proportionately the most. According to these results, technical change in agriculture benefits all broad income groups, but makes the distribution of incomes *more unequal.*

APEX is capable of going beyond these results, however, to take account of the different bundles of goods purchased by these five household groups and the changes in their respective prices. When this is done, a *reversal* of the income distributional results described above is found. These results are shown in the third and fourth columns of Table 5.

Table 5.— Change in Household Incomes
as a Result of Technical Change Experiment
(Percent)

Household (quintile)[a]	Nominal disposable incomes	Deflated by aggregate CPI	Deflated by household-specific CPI	Change in household-specific CPI
1	0.550	0.956	1.182	-0.631
2	0.584	0.990	1.162	-0.529
3	0.597	1.003	1.113	-0.515
4	0.600	1.006	1.043	-0.443
5	0.686	1.092	0.966	-0.280

[a] Quintile 1 is the poorest and quintile 5 is the richest.

The household-specific consumer price index changes shown in the third column reflect the differences among the households in their respective expenditure patterns, estimated from the Philippines' Family Income and Expenditure Survey data.[6] Household 1's expenditure shares for food (cereals

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[6] See Table 6, derived from Balisacan (1994).

and meat products) is the highest of the five households, consistent with the fact that it corresponds to the poorest quintile group. Table 6 shows, in the last column, that the prices of items forming the largest part of household 1's expenditures decline relative to other consumer goods prices. Thus, the household-specific consumer price index (CPI) for the poorest households fall the most.

The final column of Table 5 now shows that when the *real disposable incomes* of the respective households is considered, the income distributional story is changed significantly. The poorest not only *gain absolutely* from the technical change (their real disposable incomes rise), but they also *gain proportionately the most*. These results indicate that technical change in Philippine agriculture *lowers* the degree of income inequality in the Philippines, rather than raising it.

The underlying reason for the observed pattern of changes in nominal disposable incomes is the fall in the prices of agricultural goods that results from the technical change. From Appendix 1, it is apparent that the CPI falls by 0.4 percent, but agricultural prices fall by 2.1 percent. The price of *palay* (unmilled rice) falls by 2.3 percent. The prices of factors of production used intensively in agricultural production thus decline relative to other factor prices. Unskilled wages fall by 0.05 percent in nominal terms (a rise of 0.36 percent when deflated by the aggregate CPI) and returns to land fall by 4.0 percent! These are the factors of production from which the poor derive their incomes. In contrast, skilled wages rise by 0.8 percent (a rise of 1.2 percent relative to the CPI). On the income side, the poor seem to lose from technical change, relative to other income groups.

Table 6.— Budget Shares and Price Changes of Consumer Goods

Household *(quintile)*	Consumer goods						
	Cereal	Meat and dairy	Beverages	Fuel	Housing	Cloth	Misc.
1	0.388	0.187	0.122	0.091	0.103	0.062	0.048
2	0.340	0.196	0.133	0.089	0.107	0.071	0.064
3	0.294	0.200	0.138	0.087	0.128	0.077	0.076
4	0.242	0.203	0.132	0.090	0.154	0.081	0.100
5	0.155	0.185	0.098	0.111	0.226	0.075	0.150
Price change	-1.26	-0.129	0.15	0.32	0.45	0.17	-0.06

Source: Budget shares derived from Balisacan (1994).

In contrast, on the expenditure side, the poor gain relative to other groups. The same decline in agricultural prices that harms them relative to others on the income side also benefits them relative to others on the expendi-

ture side. The prices of food fall when agricultural product prices fall. This benefits the poorest income groups the most, because they are the group for which food represents the highest proportion of total expenditure.

CONCLUSIONS

This paper reports the results of an analysis of the distributional effects of technical change in Philippine agriculture. The analysis utilizes a recently constructed 41-sector, 50-commodity applied general equilibrium (AGE) model of the Philippine economy, the APEX model.

Over the period 1960 to 1984, the Philippines' real national output per head of population increased at around 2.8 percent per annum. The results, estimated using the APEX model, indicate that technical change in Philippine agriculture over the same period raised real national income at the annual rate of 0.8 percent, holding population constant. These results imply that around 30 percent of the growth of per capita output that occurred in the Philippines was due to technical progress in agriculture alone. All quintile groups of the income distribution benefited in real terms, and the poorest quintile group benefited proportionately the most; income inequality was thus *lessened* by this technical change.

As is well known, political events also took place in the Philippines over this period that operated in opposite directions from the above effects—by worsening income distribution and reducing the rate of economic growth. Nevertheless, the results imply that the technical change that occurred in Philippine agriculture during this period raised incomes, reduced poverty, and improved the income distribution, compared with what would *otherwise* have happened, had that technical change not occurred.

The income distributional effects of past rates and factor biases of technical change in Philippine agriculture prove to depend critically on three matters: differential changes in the returns to primary factors of production; the distribution of returns between those factors of production that are mobile across industries and those which are not; and the relationship between changes in the prices of final consumer goods and the expenditure patterns of different income classes. Analyses that fail to address any one of these issues could easily produce false conclusions.

Capturing the income distributional effects of technical change requires dealing with the interaction of a great number of economic variables. This is what general equilibrium models like APEX are capable of doing well. For general equilibrium models to be worthy of being taken seriously, however, they must possess a sensible and transparent structure, they must be fully documented, and they must be empirically based. APEX meets each of these requirements. It is especially notable that the behavioral parameters underlying the APEX model are based *solely* on original econometric estimates of the relevant parameters. These estimates were the result of a large research program conducted by the authors and their colleagues, using Philippine

data.[7]

The APEX general equilibrium model represents some 30 person-years of professional research input. The results summarized in this paper indicate that an effort of this magnitude is required to do justice to the analysis of an economic phenomenon as complex as technical change in the agricultural sector of a large developing country. Clearly, the cost of such a research effort is high, but the resulting analytical tool is capable of shedding much needed light on policy issues of great social importance. Moreover, it is significant that once it is built, the research tool so constructed can subsequently be used to analyze a wide range of policy issues, concerning any part of the economy represented in the model.

It would be quite wrong to suggest that a large AGE model like the one discussed in this paper is required for satisfactory analysis of *any* policy issue. For many commodity-specific policy questions, simple partial equilibrium analysis may be sufficient. But for more complex policy issues, involving the interactions among many markets, a general equilibrium framework of some kind is essential. AGE models like APEX offer the capability of using efficiently all available information on the structural features and related behavioral parameters characterizing the economic system. They are capable of being updated as this information base is improved and, due to advances in computing technology, they are becoming increasingly user-friendly.

Like all such analytical tools, AGE models in practice may be well or poorly constructed, and they are capable of being misused. But the analytic power they offer is so great that development policy analysts should not dismiss their potential contribution to our understanding of the development process.

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[7] See footnotes † and [3].

CITATIONS

Chowdhury S. Ahammed, and Robert W. Herdt, 1983. "Farm Mechanization in a Semi-Closed Input-Output Model: the Philippines," *American Journal of Agricultural Economics*, Vol. 65, pp. 516-25.

Arsenio M. Balisacan, 1993. "Agricultural Growth, Landlessness, Off-farm Employment, and Rural Poverty in the Philippines," *Economic Development and Cultural Change*, Vol. 41, pp. 533-62.

_____, 1994. "Parameter Estimates of Consumer Demand Systems in the Philippines," in Peter Warr, ed., *The APEX General Equilibrium Model of the Philippine Economy*, Australian Centre for International Agricultural Research, Canberra, forthcoming.

Cynthia Bantilan, 1989. "Production in Philippine Rice Monoculture," paper presented at the Symposium on Quantitative Analysis of Agricultural Development, Philippine Institute of Development Studies, Makati, The Philippines, August 18, mimeo.

Romeo M. Bautista, 1986. "Effects of Increasing Productivity in a Multisectoral Model for the Philippines," *Agricultural Economics*, Vol. 1, pp. 67-82.

Ramon L. Clarete and Marie Angelique C, Cruz, 1994.   "The General Equilibrium Data Set of the APEX Model," in Peter G. Warr, ed., *The APEX General Equilibrium Model of the Philippine Economy*, Australian Centre for International Agricultural Research, Canberra, forthcoming.

Ramon L. Clarete and Peter G. Warr, 1994. "The Theoretical Structure of the APEX Model of the Philippine Economy," in Peter G. Warr, ed., *The APEX General Equilibrium Model of the Philippine Economy*, Australian Centre for International Agricultural Research, Canberra, forthcoming.

George Codsi, K.R. Pearson and Peter J. Wilcoxen, 1991. "General Purpose Software for Intertemporal Modelling," *Impact Working Paper* , No.IP-51 University of Melbourne, Melbourne, Victoria, Australia.

Ian A. Coxhead, 1992. "Environment-Specific Rates and Biases of Technical Change in Philippine Agriculture," *American Journal of Agricultural Economics*, Vol. 74, pp. 592-62.

Ian A. Coxhead and Peter G. Warr, 1991. "Technical Change, Land Quality and Income Distribution: A General Equilibrium Analysis," *American Journal of Agricultural Economics*, Vol. 73 , pp. 345-60.

_____, 1992. "Poverty and Welfare Effects of Technical Change: A General Equilibrium Analysis for Philippine Agriculture," University of Wisconsin-Madison, Department of Agricultural Economics Staff Paper Series.

Peter B. Dixon, B. R. Parmenter, John Sutton, and D.P. Vincent, 1982. *ORANI; A Multisectoral Model of the Australian Economy*, North-Holland Publishing Company, Amsterdam.

Robert E. Evenson and Moises L. Sardido, 1986. "Regional Total Factor Productivity Change in Philippine Agriculture," *Journal of Philippine Development* , Vol. 13, pp. 40-61.

Walter P. Falcon, 1970. "The Green Revolution: Generations of Problems,"

American Journal of Agricultural Economics, Vol. 52, pp. 698-710.

Carl H. Gotsch, 1972. "Technical Change and the Distribution of Income in Rural Areas," *American Journal of Agricultural Economics*, Vol. 54, pp. 326-41.

Yujiro Hayami and Robert W. Herdt, 1977. "Market Price Effects of Technological Change on Income Distribution in Subsistence Agriculture," *American Journal of Agricultural Economics*, Vol. 59, pp. 245-56.

Yujiro Hayami and Vernon W. Ruttan, 1985. *Agricultural Development: An International Perspective*, Johns Hopkins University Press, Baltimore.

Cezary A. Kapuscinski and Peter G. Warr, 1994. "Estimation of Armington Elasticities for the APEX Model," in Peter G. Warr, ed., *The APEX General Equilibrium Model of the Philippine Economy*, Australian Centre for International Agricultural Research, Canberra, forthcoming.

Medhi Krongkaew, 1993. "Poverty and Income Distribution," in Peter G. Warr, ed., *The Thai Economy in Transition*, Cambridge University Press, Cambridge.

Ma. Nimfa F. Mendoza and Peter G. Warr, 1994. "Non-Agricultural Production Parameters for the APEX Model," in Peter G. Warr, ed., *The APEX General Equilibrium Model of the Philippine Economy*, Australian Centre for International Agricultural Research, Canberra, forthcoming.

Jaime B. Quizon and Hans P. Binswanger, 1983. "Income Distribution in Agriculture: A Unified Approach," *American Journal of Agricultural Economics*, Vol. 65, pp. 526-38.

V. V. Bhanoji Rao, 1988. "Income Distribution in East Asian Developing Countries," *Asian-Pacific Economic Literature*, Vol. 2, pp. 26-45.

C. Peter Timmer, 1988. "The Agricultural Transformation," in Hollis Chenery and T. N.. Srinivasan, eds., *Handbook of Development Economics*, Vol. 1, North Holland, Amsterdam.

Peter G. Warr, 1994a. "Agricultural Production Parameter Estimates for the APEX Model," in Peter G. Warr, ed., *The APEX General Equilibrium Model of the Philippine Economy*, Australian Centre for International Agricultural Research, Canberra, forthcoming.

Peter G. Warr, ed., 1994b, *The APEX General Equilibrium Model of the Philippine Economy*, Australian Centre for International Agricultural Research, Canberra, forthcoming.

World Bank, 1990. *World Development Report, 1990*, Washington, D. C.

_____, 1992. *World Development Report, 1992*, Washington, D. C.

Appendix.—Technical Change Experiment, Summary of Results

Note: All results are in percentage changes unless otherwise indicated. Exogenous variables and the specified changes in their levels are each marked with an asterisk (*).

A. Macro Results

A.1   Overall Economy

Gross Domestic Product

Nominal (local currency)	0.525
Real	0.940
Consumer Price Index	-0.406
GDP Deflator	-0.415

A.2   External Sector

Export Revenue (foreign currency)	0.413
Import Bill (foreign currency)	0.395
Trade Deficit (in levels, foreign currency)*	0.000*

A.3   Government Budget

Revenue

Nominal (local currency)	-1.084
Real	-0.678

Expenditures

Nominal (local currency)	0.052
Real	0.457
Budget Deficit (in levels, local currency)	1.978

A.4   Household Sector

Consumption

Nominal (local currency)	0.634
Real	1.040
Savings (in levels, local currency)*	0.000*

B. Sectoral Results

Commodity Supplies

B.1   Industry Groups

Primary Industries	0.625
Natural Resources	1.027
Agricultural Processing	0.502
Other Manufacturing	0.368
Services	0.000

B.2   Regional Composite Agricultural Outputs

Luzon	3.226
Visayas	0.429
Mindanao	2.322

B.3   Specific Industries

Irrigated palay	1.618
Non-irrigated palay	1.180
Corn	4.304
Coconut	5.214
Sugarcane	3.210
Banana and other fruits and nuts	5.391
Vegetables	0.791
Rootcrops	0.938
Other commercial crops	5.095
Hogs	1.515
Chicken and poulty products	1.811
Other Livestock	1.621

C. Income Distribution Results

C.1   Functional

Nominal factor income changes

HH1 (Poor)	0.289
HH2	0.320
HH3	0.337
HH4	0.349
HH5 (Rich)	0.471

Real factor income changes (deflated by aggregate CPI)

HH1 (Poor)	0.695
HH2	0.726
HH3	0.743
HH4	0.755
HH5 (Rich)	0.877

C.2   Household

Nominal household expenditure changes

HH1 (Poor)	0.550
HH2	0.584
HH3	0.597
HH4	0.600
HH5 (Rich)	0.686

Real household expenditure changes (deflated by aggregate CPI)

HH1 (Poor)	0.956
HH2	0.990
HH3	1.003
HH4	1.006
HH5 (Rich)	1.092