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Modelling Equity and Efficiency in Agricultural Production Systems

INTRODUCTION

Over the last decade, the attention of the development community has shifted from preoccupation with economic growth to emphasis on distribution. The development process is increasingly being assessed in terms of equity as well as growth. The traditional view held a distinct trade-off between efficiency and equity. Recent experience (particularly in Yugoslavia, China, and Korea), however, has cast doubt on this view. Similarly, the Kuznets hypothesis that inequality increases and then decreases, as income per caput grows, is no longer viewed as an iron-clad law. For example, on the basis of inequality measures in the Taiwan area (measured by the Gini coefficient G), Fei, Ranis, and Kuo have observed that:

> The Kuznets effect is a complex phenomenon that needs to be disaggregated. In its extreme form, it really is relevant only to the non-agricultural sector. In countries where agricultural activity is important – as it is in Taiwan and in most LDCs – growth does not necessarily conflict with equity, even before the turning point has been reached.

In the case of Taiwan, this study provides convincing evidence that the tendency of non-farm growth to increase G can be overpowered by the tendency to more egalitarian farm income growth; thus, the net effect can be to reduce inequality.

Thus, the distinct possibility exists that greater efficiency in resource use will assist in the achievement of a more equitable growth path as well as higher growth rates. The effective utilization and adoption of agricultural technology may, in fact, result in labour demand increasing faster than its supply, as well as food supply increasing faster than its demand. Recognizing the dialectic interactions between technological and institutional innovations, Hayami has even argued that the first step in designing an effective agricultural development policy is to recognize that, in the long run, there is no trade-off between growth and equity.

The vast majority of analytical frameworks that have been advanced for the evaluation of policies in LDCs, however, are primarily based on macro representations of the economy. Hence, few solutions have been offered that enhance both efficiency and equity. In evaluating equity issues, conventional macro or market-oriented analytical frameworks suffer serious limitations. For example, Krishna recently noted the fundamental inconsistency between recognizing the key characteristic of backwardness as pervasive fragmentation of labour and capital markets but yet using the ordinates of supply curves estimated from crude aggregate production or sales data as measures of the true opportunity costs of resources. Krishna further criticizes traditional analysis of aggregate gains and losses noting that the distribution of gains and losses between producers, as a group, and consumers, as a group, is of much less interest to policymakers than the distribution between rich producers and consumers and poor producers and consumers. Conventional welfare analysis, which is based on aggregate supply and demand relationships, sheds very little light on the distribution of gains between income brackets. When other objectives and structural features of poor economies are kept in mind, major arguments exist for second-best interventions which are neglected by conventional model formulations. Only by disaggregating conventional demand and supply analysis is it possible to correct some of the serious deficiencies of existing model formulations. This requires micro-based model formulations with explicit consideration of multiple objectives, in particular the equity and efficiency outcomes resulting from the implementation of various policies affecting the growth process.[1]

The purpose of this paper is to advance such a micro methodology for evaluating the efficiency and equity outcomes of various agricultural growth policies. The methodology is illustrated by way of a specific theoretical example. The example is necessarily simplified so that we may analytically derive the implications of the model by way of comparative statics. However, much more generality can be achieved in the context of actual empirical applications. A comparative static evaluation allows us to compare a host of different policies or governmental interventions. The model design is also readily amendable for the investigation of efficiency and equity consequences of integrated, comprehensive sets of policies. In an empirical context the model formulation admits the possibility that, for example, even though the distribution of income or landholdings might be quite stable under a single policy régime, egalitarian development strategies may be determined by integration of various policies. In fact, single policies, under certain economic environments, are shown to enhance efficiency as well as equity.

The major characteristics of the model formulation are presented in the next section. The mathematical representation of the model formulation is outlined in the third section, which emphasizes microeconomic behaviour as well as the aggregate or macro relationships for the agricultural production system. The fourth section presents some selected comparative static results for a number of governmental policies.[2] Finally, the last section presents some concluding remarks.

THE GENERAL METHODOLOGY

The equity and efficiency impacts of selected governmental policies have been addressed by a number of different formulations, most of which are based on aggregate relationships. Generally, aggregate relationships are specified for an agricultural sector and a non-agricultural sector. The microeconomic foundations of these frameworks, however, are not generally specified. As a result, the thorny problems of aggregation are pushed aside.

The formulation in this paper, however, focuses on the agricultural sector alone in an effort to look at distributional issues within the sector. The sector is viewed as an aggregation of its parts; thus, the potential implications of various policies for both efficiency and equity are represented explicitly. The impact of governmental policies on agricultural production systems from the standpoint of both efficiency and equity is internally consistent at both the micro-level and the aggregate level. Within agricultural production systems, the general equilibrium effects of various policies are captured.

In the model formulation, land assumes a crucial role. As noted in numerous previous studies, the distribution of land has been found to be the dominant determinant of the distribution of income and access to non-land inputs (see, for example, Repetto and Shah, 1975 and several studies cited by Lappe and Collins, 1977). Given this focus, the model is structured to be able to evaluate land reform or the effects of redistributing land. The model formulation admits the possibility that redistribution of land is economically feasible without loss of output owing to the decline in the average productivity of land with an increase in farm size.

Along with the emphasis on the distribution of land, the model incorporates a number of important features including uncertainty, varying degrees of risk aversion, both fixed and variable costs of technology adoption, and credit constraints. It can thus be shown that the equity and efficiency effects of various policies depend critically upon the distribution of credit and risk preferences across various segments of the farm population. Although the example does not formally incorporate the distribution of human capital, it is a feature that can be easily accommodated with the methodology.

The driving force for growth in the model centres on new technology. Following the empirical results reported in Hayami, Ruttan, and Southworth, 1979, this feature of the model formulation simply recognizes that most output growth results from technology. Following this assumption, the model specification at the micro-level is essentially that which has emerged from the adoption literature. (For a recent survey, see Feder, Just, and Zilberman, 1982.) In this literature, the conventional wisdom is that constraints to rapid adoption involve factors such as the lack of credit, limited access to information, aversion to risk, inadequate farm size, insufficient human capital, absence of equipment to relieve labour shortages (thus preventing timely operations), and chaotic supply of complementary inputs (such as seeds, chemicals, and water).

Many development projects have sought increased growth through technological adoption by removing some of these constraints, for example, by introducing facilities to provide credit, information, orderly supply of necessary and complementary inputs, infrastructure investments, marketing networks, and the like. Some of these policies affect the fixed costs of adoption while others influence the variable costs. Thus, a general model specification must deal with both the discrete and continuous aspects of technological choice. This complicates the model specification but allows it to be used as a vehicle for evaluating a wide array of policies. In the model formulation presented below, the policies that are readily admitted include export subsidies or threshhold prices, credit funding enhancement, credit subsidies, fixed crop insurance, price stabilization, input subsidies, and extension programmes. This set of policies includes a number of instruments often pursued by governments of developing countries.

A complete analytical framework for investigating adoption processes at the farm level and its implications for both efficiency and equity must be based on a decision-making model for individual farmers determining both the extent and intensity of new technology utilization. Generally, decisions of a farm in such a model are assumed to be derived from the maximization of expected utility (or expected profit) subject to land availability, credit, and other constraints. Profit is a function of the farmer's choice of crops and technology. It, therefore, depends on his discrete selection of a technology from a mix of technologies and on a continuous choice of intensity with which to use the modern technology package.

To illustrate these points, the example below uses a stylized model involving two discrete technologies, traditional and modern. Given the discrete technology choice, income depends continuously on land allocation among crop varieties, the production function parameters of these crop varieties, the prices of inputs and outputs, and the annualized costs associated with the discrete technological choice. Given the land and variable input values, the perceived income may be regarded as a random variable embodying objective uncertainties with respect to yields and prices and subjective uncertainties associated with the farmer's incomplete information on the production function parameters.

The treatment of uncertainty and risk aversion must assume a central role in the model formulation if the risky perception of new technologies by individual farmers is to be captured. For this purpose there have been two major methods employed in both theoretical and empirical models. One approach employs *ad hoc* safety rules which are convenient and useful for planning purposes, especially using linear and nonlinear programming techniques (Roumasset, Boussard, and Singh, 1979). The other methodology, with a more sound axiomatic foundation, assumes expected utility maximization by farmers. The example below uses the latter approach. Utility of individual farmers is assumed to be negative exponential utility with normal yield distributions or quadratic utility. Under these assumptions, each farmer's objective function is linear in the means, variances, and covariances of revenues and is quadratic in the areas allocated to different crop varieties. The linear risk coefficient is assumed to vary with farm size thus preserving the tendency of absolute risk aversion to decline as farm size increases.

Most adoption studies also assume that the amount of land a farmer can operate each period is given; thus, he maximizes his expected utility subject to land availability. Imperfections in the credit and labour markets may also result in credit and labour availability constraints that affect the actual choice. The case of binding land and credit constraints is considered below, but labour constraints can be considered in a similar manner.

Once such a micro model of the decision-maker's problem is specified so as to be sensitive to the factor affecting individual farmers in developing agriculture, the methodology is applied as follows. First, response functions depicting the reactions (decisions, income, and welfare) of individual farmers to various policy, market, and informational factors is derived. Second, the distribution of information, human and capital resources, and preferences among farmers is estimated or specified. Third, the equity and efficiency performance measures of interest are determined by integrating the reaction functions of farmers with respect to the distribution of information, human and capital resources, and preferences among farmer. This integration can be done analytically in theoretical work and numerically in empirical work. Finally, the equity and efficiency effects of various policies can be analyzed accordingly.[3]

AN EXAMPLE OF THE METHODOLOGY

To develop an explicit example of this approach that can illustrate the types of results that can be obtained, consider initially a single farm with fixed landholdings L valued at price p_L and a traditional technology involving a subjective distribution of net returns per hectare $\pi_0 = p_0 y_0$ with mean $E(\pi_0) = m_0$ and variance $V(\pi_0) = \sigma_0$ where p_0 and y_0 are the price and yield, respectively under the traditional technology. Suppose a new technology is introduced under which the farmer can allocate some of his land to the traditional crop (at traditional costs) and some of his land to a new crop (or a new method of producing the same crop).

The second crop (technique), the 'modern crop', may be a high-yielding variety or a cash crop utilizing a modern input such as fertilizers, insecticides, and improved seeds. On the other hand, it may be more vulnerable to weather variations so that there is a relatively greater degree of uncertainty regarding the returns per hectare. Additional (and subjective) uncertainty may also accompany the modern crop due to the fact that the farmer is less familiar with the new technology. Considering this factor, the modern crop may be viewed as more risky even if, in reality, it is not more susceptible to extreme weather situations than the traditional crop.

The production of the modern crop is presumed to require a cost of w for the modern input per hectare to attain a subjective distribution of net returns per hectare π_1 with mean $E(\pi_1) = m_1$ and variance $V(\pi_1) = \sigma_1$. The (opportunity) cost of funds used to finance the modern input is given by r so that $\pi_1 = p_1 y_1 - w(1 + r)$ where p_1 and y_1 are the price and yield of the modern crop, respectively, and $p_1 y_1$ is normally distributed. Also, suppose that net returns of the traditional and modern crops are correlated with $\mathrm{corr}(\pi_0, \pi_1) = \rho$. Net returns for both technologies are assumed to be generated by a multivariate normal distribution with the relevant covariance matrix assumed to be positive definite. Also note that the variances and covariances include *subjective* uncertainty about yields and market access (prices) and may thus be influenced by both experience and extension efforts.

The farmer must either allocate all his land to the traditional technology or incur a fixed set-up cost, k, for the new technology in which case he can allocate his land in any proportion between the two technologies. Thus, the investment decision is a discrete choice whereas the land-allocation decision is a continuous choice.[4] In addition to the fixed set-up cost k for which the annualized cost is rk, the farmer also incurs a variable cost, w per hectare, for adoption. Both of these costs must be considered in the context of available credit K in making the adoption decision. The credit constraint is

$$\mathrm{I}(k + wL_1) \leq K$$

where $\mathrm{I} = 0$ if the modern technology is not adopted, $\mathrm{I} = 1$ if the modern technology is adopted, and L_1 is the amount of land allocated to the new technology.

Now assume that the farmer is risk averse with utility function $U(\cdot)$ defined on wealth, $U' >$, $U'' \leq 0$. Suppose that wealth, W, at the end of each season is represented by the sum of land value, $p_L L$, and the net return from production. Where L_0 is the amount of land allocated to the traditional technology, the decision problem is thus:

$$\max_{\substack{I = 0, 1 \\ L_0, L_1}} EU\,[p_L L + \pi_0 L_0 + I\,(\pi_1 L_1 - rk)] \qquad [1]$$

subject to

$$L_0 + IL_1 \leq L$$
$$I\,(k + wL_1) \leq K$$
$$L_0, L_1 \geq 0.$$

The results below assume that risk aversion is not so great or returns so poor as to prevent use of all available land. Thus, the land constraint can be replaced by a strict equality.

To solve this decision problem, first consider the choice of land allocation given the adoption decision. Assuming full utilization, the optimal decision with $I = 0$ is $L_0 = L$. Thus expected utility is

$$U_0(L) = EU[(p_L + \pi_0) L]. \qquad [2]$$

Alternatively, given adoption, the objective of the decision problem in [1] becomes

$$\max_{L_0, L_1} EU[p_L L + \pi_0 L_0 + \pi_1 L_1 - rk] \qquad [3]$$

subject to

$$L_0 + L_1 \leq L$$
$$k + wL_1 \leq K$$
$$L_0, L_1 \geq 0.$$

The solution to this problem is approximated by (see JRZ):

$$L_1 = \overline{L}_1 \equiv \begin{cases} 0 & \text{if } L_1^* < 0 \text{ or } k > K \\ L_1^* & \text{if } 0 \leq L_1^* \leq L \text{ and } (K-k)/w > 0 \\ (K-k)/w & \text{if } L > L_1^* > (K-k)/w > 0 \\ L & \text{if } (K-k)/w > L \text{ and } L_1^* > L \end{cases} \qquad [4]$$

and $L_0 = \overline{L}_0 \equiv L - \overline{L}_1$

where

$$L_1^* = \frac{E(\Delta\pi)}{\phi V(\Delta\pi)} + LR \qquad [5]$$

$$R = \frac{\sigma_0^2 - \rho\sigma_0\sigma_1}{\sigma_0^2 + \sigma_1^2 - 2\rho\sigma_0\sigma_1} \qquad [6]$$

$$\Delta\pi = \pi_1 - \pi_0 \qquad [7]$$

$$\phi = \frac{-U''(\overline{W})}{U'(\overline{W})} \qquad [8]$$

$$W = p_L L + m_0 L + E(\Delta\pi) L_1 - rk. \qquad [9]$$

Note that ϕ is the Arrow-Pratt coefficient of absolute risk aversion at expected wealth (see Arrow, 1971).

This result is intuitively clear from Figure 1 upon noting that (3) is a concave programming problem with linear constraints. Assuming full utilization of land, the optimal solution must lie on the line ac. Note thatL_1^* is the optimal solution for L_1 when negative choices for land quantities are possible (corresponding to the broken lines in Fig. 1). Thus, by concavity of the objective function, the optimum is at point c if $L_1^* < 0$. If credit is abundant (for example $K = K_1$ in Fig. 1), then the optimum is at point *a* if $L_1^* > L$. However, if credit is insufficient to allow complete adoption such as if $K = K_0$ in Figure 1, then the segment ab is infeasible because of credit limitations. Thus the optimum is at point *b* if $L_1^* > (K - k)/w$.

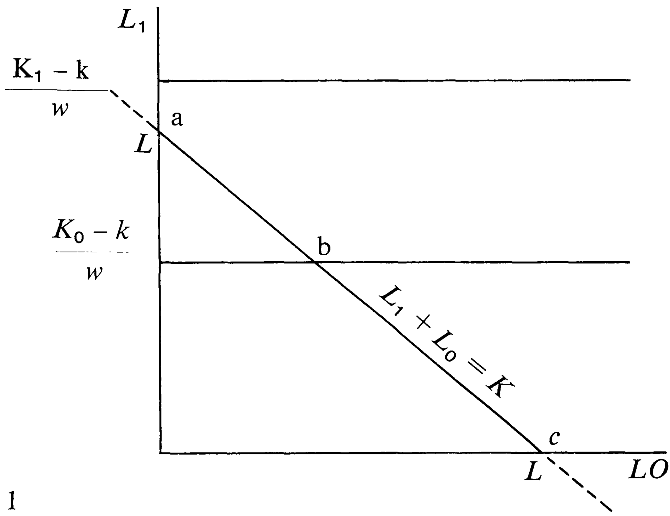

Fig. 1

To determine the technology choice, let

$$U_1\ (L, \bar{L}_1) = EU[p_L L + \pi_0 (L - \bar{L}_1) + \pi_1 \bar{L}_1 - rk] \qquad [10]$$

Assuming either that the farmer is myopic (or considers future periods to be like the current one), the farmer selects the traditional technology if $U_0 > U_1$ and selects the new technology if $U_1 > U_0$.

Corresponding to (4), the expected 'welfare' of each farmer can be represented as follows:

$$\bar{U}\ (L) = \begin{cases} EU\left[\ (p + \pi_0)\ L\ \right], & \text{if } L_1^* < 0 \text{ or } k < K \\ EU\left[\ p_L L + \pi_0(L - L_1^*) + \pi_1 L_1^* - rk\ \right], & \text{if } 0 < L^* \leq L \text{ and } \dfrac{K-k}{w} > 0 \\ EU\left[p_L L + \pi_0\left(L - \dfrac{K-k}{w}\right) + \pi_1 \dfrac{K-k}{w} - rk\right], & \text{if } L > L_1^* > \dfrac{K-k}{w} > 0 \\ EU\ [(p_L + \pi_1)\ L - rk], & \text{if } \dfrac{K-k}{w} > L \text{ and } L_1^* > L. \end{cases} \qquad [11]$$

In this context, equity and efficiency issues can be investigated quantitatively once the distribution of microparameters among farmers is specified. The results here focus on the distribution of risk preferences, farm size, and credit availability with the farm(er)s assumed to be identical in other respects. This is done by first specifying a distribution of farm size and then specifying a relationship between farm size and risk preferences and credit.

Suppose the distribution of landholdings follows a Pareto distribution with density function

$$f(L) = (\gamma - 1)^{\gamma} \gamma^{1-\gamma} \overline{L}^{\gamma} L^{-\gamma-1} \quad \text{for } \frac{\gamma - 1}{\gamma} L < L < \infty; \gamma > 1. \quad [12]$$

Note that the average farm size is L and that γ is a measure of concentration of the farm size distribution. As γ increases, the farm size distribution becomes more equitable with both small farms tending to become larger and large farms tending to become smaller.

Given this distribution of farm size, risk preferences as reflected by the coefficient of absolute risk aversion (ϕ) are assumed to be related to initial wealth or farm size following the equation

$$\phi = \widetilde{B}\ W_0^{-\eta} = BL^{-\eta}, \quad 0 < \eta < 1, \qquad [13]$$

where initial wealth is $W_0 = p_L L$ and $\widetilde{B} = Bp_L^{-\eta}$. Absolute risk aversion is assumed to be constant for each individual farmer; however, $\eta > 0$ implies that larger farmers have less absolute risk aversion and $\eta < 1$ implies that larger farmers have more relative risk aversion following Arrow's arguments.[5] To simplify, the availability of credit is also assumed to be related to initial wealth or, equivalently, farm size, following $K = aL$.

For constant absolute risk aversion of individual farmers, the expressions in (11) can be represented as certainty equivalents. In particular, given (11), (12), and (13) and constant absolute risk aversion, the certainty equivalent is:[6]

$$C(L) = \begin{cases} U_0^* = (p_L + m_0)\,\overline{L} - \dfrac{B}{2}\sigma_0^2\,\overline{L}^{2-\eta}, \text{ if } 0 < L_1 \leq \hat{L}_1 \\[2ex] U_{11}^* = \left[p_L + m_0 + E(\Delta\pi)\dfrac{a}{w} \right] \overline{L} - \dfrac{B}{2}\dfrac{k^2}{w^2}\, V(\Delta\pi)\, L^{\eta} \\[2ex] \quad + B\dfrac{k}{w}\,\mathrm{v}(\Delta\pi)\,\dfrac{a}{w} + R_v\,\overline{L}^{1-\eta} - \dfrac{B}{2} V\pi_0 + \dfrac{a}{w}\,\Delta\pi\,\overline{L}^{2-\eta} \\[2ex] \quad - E(\Delta\pi)\dfrac{k}{w} - rk, \text{ if } \hat{L}_1 < L_1^* \leq \hat{L}_2 \\[2ex] U_{12}^* = (p_L + m_1)\,\overline{L} - \dfrac{B}{2}\sigma_1^2\,\overline{L}^{2-\eta} - rk, \text{ if } \hat{L}_2 < L_1 \leq \hat{L}_3 \end{cases} \qquad [14]$$

$$U^*_{13} = [p_L + m_0 (1 - R) + m_1 R]\bar{L} + \frac{E^2 (\Delta\pi)}{2 BV(\Delta\pi)} L^\eta - \frac{B \sigma_0^2 \sigma_1^2 (1 - p^2)}{2 V(\Delta\pi)} \bar{L}^{2-\eta} - rk, \text{ if } L_1 > \hat{L}_3.$$

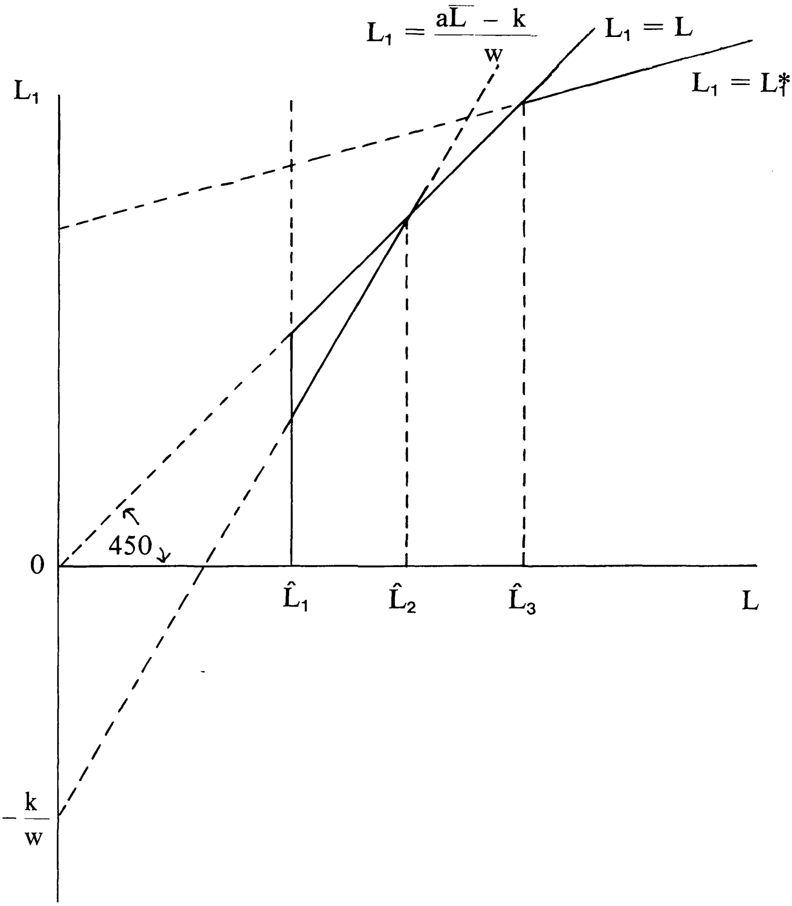

Fig. 2

The four expressions appearing in (14) thus provide a basis for evaluating the welfare effects (compensating or equivalent variation) of policy changes (Just, Hueth, and Schmitz, 1982). The four segments are graphically displayed in figure 2. In this figure, the intensity of adoption is measured by L_1 which is physically constrained to lie between the lines $L_1 = L$ and $L_1 = 0$. It is constrained to lie on or below the credit limitation boundary, $L_1 = (K$

$-k)/w = (aL - k)/w$. Subject to these limitations, the intensity of adoption follows the expression derived in (5) for L_1^*. Below $\hat{L}_1$, farm size is insufficient for fixed costs to be adequately spread to make adoption worthwhile. Between this boundary and $\hat{L}_2$, adoption becomes desirable but credit limitations prevent full adoption. On the interval defined by the bounds $\hat{L}_2$ and $\hat{L}_3$, full adoption occurs since credit becomes non-binding. At farm size $\hat{L}_3$ and above perceived risk becomes sufficiently large to induce diversification among the two technologies.

EQUITY AND EFFICIENCY

On the basis of the above model, a number of analytical results have been derived in JRZ. These analytical results focus on the efficiency and equity effects of various governmental policies. The results clearly demonstrate that farm size within each of the decomposed class of farmers are unaffected by some policies and strongly influenced by others. For example, policies that enhance the perceived mean return of the modern technology (for example export subsidies and extension programmes) have no effect on the welfare of small non-adopting farmers, a unitary effect on full adopting farmers, and a less than unitary effect on partial adopters, in the case where the major barriers to adoption are risk aversion and set-up cost. In the case where the major barriers to adoption are credit instead of set-up cost, once again we have no effect on the small non-adopting farms, a greater than unitary effect on partial adopting farms, and a unitary effect on full adopting farms.

Turning to specific policies, first consider export subsidies or threshold pricing. For these policies, if the new technology pertains to a new crop, small non-adopters are unaffected while larger full adopters and partial adopters become better off thus widening the income distribution. Where risk aversion and set-up cost are the major barriers to adoption, the minimum scale required for adoption declines while the maximum size of full-adopting farms increases; thus, more adoption is induced. If the new technology pertains to an existing crop, then export subsidy or threshold pricing policies will cause an increase in aggregate farm income if the major barriers to adoption are credit and set-up cost. If the major barriers to adoption are risk aversion and set-up cost, the minimum scale required for adoption declines while the maximum size of full-adopting farms increases and the overall level of adoption is enhanced. However, if the major barriers to adoption are credit and set-up cost alone, adoption is unaffected and, thus, there are no efficiency effects. Hence, under export subsidies or threshold pricing policies, it is possible to achieve efficiency with less equity, no efficiency with less equity, and efficiency with improved equity.

In the case of a credit subsidy policy, small non-adopters are unaffected, while both larger partial adopters and full adopters are made better off. In the case where the major barriers to adoption are risk aversion and set-up costs, the minimum scale required for adoption declines while the maximum size of fully adopting farms increases and overall adoption is enhanced. If credit and set-up costs are the major barriers to adoption, then technological adoption is unaffected. Thus, this policy can result in efficiency with less equity or no efficiency with less equity.

The effect of a public credit programme that increases credit availability at the market rate of interest is to augment aggregate farm income if credit and set-up cost are the only major barriers to adoption. Under these barriers, small non-adopters and large full adopters are unaffected while the well-being of mid-size partial adopters is increased; the minimum scale required for both partial adoption and full adoption is decreased so that the overall adoption increases. Hence, for this policy instrument, growth with greater equity can be achieved depending on the distribution of available credit.

Crop insurance or price stabilization schemes have effects which depend upon whether the new technology pertains to a new crop or the existing crop. In the case of the new crop, these schemes improve aggregate farm income if the major barriers to adoption are risk aversion and set-up cost while farmer welfare is unaffected if the major barriers to adoption are only credit and set-up cost. For the case of the existing crop, the effect of actuarially fair crop insurance or mean-preserving price stabilization is to improve aggregate farm income according to the expected utility criterion if the major barriers to adoption are risk aversion and set-up cost, while farmer well-being is unaffected in the case where the major barriers to adoption are credit and set-up cost. Hence, this policy can result in growth with less inequity, no growth with no change in equity, and greater efficiency with increased equity in an expected income sense.

The effect of an input subsidy policy is to increase aggregate farm income. Small non-adopting farmers are unaffected, while the welfare of both fully adopting and partially adopting farmers is improved. In the case where risk aversion and set-up costs are the major barriers to adoption, the minimum scale required for adoption decreases while the maximum size of full-adopting farms is increased so the overall adoption increases. In the case where the major barriers to adoption are credit and set-up costs, the minimum scale required for adoption is unaffected while the minimum size of full adopting farms decreases so that overall adoption increases. Thus, it follows that this particular policy by itself results in greater efficiency with inequity.

Governmental intervention involving a subsidy on the fixed cost of adoption leaves small non-adopting farms unaffected while the welfare of larger fully and partially adopting farmers increases. The minimum scale required for adoption declines as the maximum size of fully adopting farms is unaffected in the case where the major barriers to adoption are risk aversion and set-up cost while the minimum scale associated with full adoption declines in the case where credit and set-up costs are the major barriers to adoption. Overall adoption increases in any case, and we are left with improved efficiency but greater inequity.

The effect of extension activities that improve farmers' subjective distributions of returns under the new technology or that reduce perceived search and learning costs connected with adoption is to increase average expected farmer welfare and the overall level of adoption. These increases are shared by larger farms with sufficient scale for adoption while farms below the minimum scale required for economic adoption are unaffected.

The effect of land-reform policies depends critically upon the nature of the barriers to adoption. For example, the effect of an increase in land endowment among adopting farmers with non-binding credit is to increase the intensity of adoption. The effect among adopting farmers with binding credit is to reduce the intensity of adoption since all land is allocated to the old technology.

The above thumb-nail sketch of the analytical results demonstrates quite clearly that single policies often prove unable to enhance both efficiency and equity. Export subsidy or threshold pricing policies prove effective in enhancing efficiency in some instances and ineffective in others. Without knowledge of the nature of the barriers to adoption, credit funding policies can be indeed precarious. We can only ensure the effectiveness of insurance or price stabilization schemes by combining such policies with credit-related policies to relieve potentially important barriers to adoption. The effectiveness of modern input subsidies also depends upon the nature of adoption barriers. Only by combining credit policies with modern input subsidies is it possible to ensure that small farmers benefit. Similarly, the influence of extension policies on equity outcomes depends upon its integration with other instruments. Only by combining extension programmes with other policies is it safe to infer that the minimum scale required for adoption will be decreased.

The above results reveal varying qualitative effects that can be achieved by different policies. They demonstrate the importance of different types of barriers to adoption and perhaps, more importantly, the need to operate with more than a single policy régime. It is particularly obvious that the pursuit of a single policy régime is most acute for small farms. The analytical results show how the pursuit of a single policy will generally result in a trade-off between efficiency and equity while a combination of policies may attain enhanced efficiency and equity simultaneously.

CONCLUSION

The static representation advanced in this paper to investigate the efficiency and equity effects of various policies can be extended in a number of directions. The dynamic counterpart of the model presented in the third section involves an intertemporal optimization problem. At the beginning of each period, the type of technology the farmer will use is determined along with allocation of land among crops and the use of variable inputs. Moreover, equations of motion for the economic environment, human and capital accumulation, can be incorporated. In this formulation, at the end of each period, the actual yields, revenues, and profits are realized. This added information, as well as the experience accumulated during the period and the information on the outcomes obtained by other farmers, can be used to update the parameters that are used in the actual decision-making process for the subsequent period.

Other potential extensions include allowing not only the degree of risk aversion to vary across farmers but their *perceived* risk as well. In a dynamic context, the model can also be generalized to allow the criterion function (utility function) to vary over time as well as across farmers. To operationalize these and other potential extensions, however, requires a significant amount of empirical estimation. Even without such extensions, the model presented in the third section requires a considerable amount of empirical estimation.

Empirical analysis must begin by decomposing the farming population into relevant classes. This decomposition can be accomplished endogenously by the specification of a discrete/continuous behavioural model. The discrete choice relates to technology, while the continuous choice is the amount of land allocated across technologies. Available secondary data can be employed by a simultaneous discrete choice model of farmer behaviour (Hanemann). The explanatory variables appearing in this model include a vector of expected returns per hectare defined by capital technology, the variances and covariances of returns defined across crops and technologies, variable cost of modern inputs, the opportunity cost of financial funds, fixed set-up costs of various technologies, available credit, and the effect of various extension and learning activities on perceived return distribution.

Estimated relationships between the above explanatory variables and discrete technology choices and continuous land allocation choices is one component of the required empirical structure. A second component is an estimation of the distribution of landholdings. A third empirical component must relate farm size or other observable information to risk preferences. Estimation of this relationship will most likely require the use of primary data from representative samples. The final empirical component requires a set of linking equations between the policy instruments and the specified explanatory variables. For example, the empirical relationship between price supports and the vector of mean returns and the covariance matrix of returns across technologies must be determined.

Armed with the above four empirical components, a number of operational uses of the proposed framework are possible. First, one can simply evaluate numerically the effects of various policies through the four empirical components to determine the most effective integration of the various policies.

Secondly, the specification of a formal criterion function would allow the search for the optimal set of policies. Various trade-off relationships or alternative weightings in a scalar criterion function including two principal performance measures, efficiency and equity, could be specified, or a host of such criteria could be investigated through parametric analysis.

Another potential use of the four empirical components relates to the notion of political economic markets. In a positive analysis of government behaviour, the four components can represent a constraint structure which, along with a specified criterion function, can be used to infer *via* revealed preference methodology the weights across both efficiency and equity (Rausser, 1982). Such a positive analysis would allow economic researchers to effectively perform a role as social critics or as organizers of rural poor as suggested by Vyas, in this volume, and Krishna, 1982; that is, if past policies imply a value scheme which in some sense deviates from the public interest, then the implicit choice of trade-offs between efficiency and equity should at least be exposed. Along similar lines, various economic interest groups could also employ the four empirical components to determine which set of policies they are prepared to support or oppose.

In the final analysis, the proposed theoretical framework and its empirical counterpart will prove to be a valuable element in the tool kit of policy analysts if and only if sound data support systems are designed and maintained. The required data support system for the proposed framework is indeed demanding. Nevertheless, the expected benefits from designing and maintaining such a data support system may far outweigh its associated cost.

NOTES

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[1]There have been some multiple-objective programming approaches advanced in the development context (e.g., Loucks) but, as yet, there is a lack of sufficient micro detail.

[2]A more lengthy version of this paper which presents the formal propositions and proofs of the comparative static results is available upon request (Just, Rausser, and Zilberman, hereafter referred to as JRZ).

[3]With this background, one can view the methodology proposed here as an application of the general approach advanced by Johanson and Sato and applied elsewhere by Hochman, Zilberman, and Just.

[4]For simplicity, the variable input level per hectare associated with the new technology is assumed here to be predetermined. Some of the ramifications of assuming variable input per hectare to be a choice variable are investigated by Just and Zilberman.

[5]K.J. Arrow, 'The Theory of Risk Aversion', in K.J. Arrow (ed), *Essays in the Theory of Risk Bearing,* Markham, Chicago, 1971, Ch. 3.

[6]Note that the expression V is derived by approximating

$$\frac{dEU}{dL_1} = E[U'(\pi_1 - \pi_0)] \simeq 0,$$

by $E\ (\Delta\pi) - \phi\ [L_1\ V\ (\Delta\pi) + L\ (p\sigma_0\sigma_1 - \sigma_0^2)[= 0$ where V donotes the variance operator and $\Delta\pi = \pi_1 - \pi_0$. Note also that the results appearing in (14) are formally derived in JRZ.

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DISCUSSION OPENING – L. GARRIDO EGIDO

I have found the model presented by Dr Just very interesting. This model, which integrates equity and efficiency, represents an important contribution and I wish to congratulate its authors.

It is, first of all, pertinent to make a preliminary comment on the concepts of efficiency and equity. Efficiency can be measured, both in physical and in monetary terms, by means of partial or global indices. Clearly, it is the latter that have to be used when measuring agricultural development, that is, this sector's technical progress. The indices used in the paper, however, are only concerned with economic factors. This is because the inclusion of social and political factors would present the problem of their quantification. Still, the concept of efficiency from both a collective and a long-term perspective, should include all aspects, like, for example, those relating to resource conservation and development, and to the attainment of an equilibrium state, of an effective social integration, and of the highest social welfare.

There is, therefore, need for a definition of these social and political objectives, upon which depend the efficiency level of agriculture, the development of which is assessed with respect to an equity level to be attained particularly via the distribution to both agricultural and non-agricultural groups of the benefits arising from such development. The question then is how to integrate these hard-to-measure elements into an agricultural development model which embodies an attempt to integrate efficiency and equity.

With respect to the distribution of the benefits from agricultural development, I wish to consider two questions.

Firstly, in most industrialized countries, modern techniques – high yield varieties, greater use of fertilizer and farm machinery and so on – have made higher yields and, as a consequence, overall agricultural productivity possible. Farmers' incomes will then be higher if agricultural prices will be kept at the same level by means of a governmental price policy. On the other hand, if agricultural prices are reduced, the benefits from agricultural development will be transferred to the consumers. Hence, the distribution of the benefits from agricultural development between farmers and non-farmers depends on Government policy, which is determined on the basis of a political option which takes the relation between farmers' and non-farmers' income levels into consideration. In the industrialized countries, however, the effort to improve the position of the agricultural sector through price manipulation has resulted in a relatively insignificant improvement. It has also resulted in production surpluses as a result of the abundant use of resources – especially labour – in agriculture. The combination of price and structural policies, as it has been implemented, has not been a solution. Could other actions be combined with these policies like, for example, direct income transfers in favour of certain agricultural groups? What should be the characteristics of these measures to ensure compatibility between efficiency and equity?

The second question concerns the different influence of technical progress in different areas. The use of new seed varieties has determined an appreciable increase in certain crops, though only in those areas for which such varieties proved appropriate. These regions have thus been able to improve their relative position *vis-à-vis* those which had to continue to use traditional varieties. Similar situations result from the use of other new techniques: mechanization, irrigation, more intensive fertilizer utilization and so forth.

From the above it follows that technical progress in the agricultural sector is either a cause of new regional disparities or it may exacerbate existing ones. This is so, even without taking into account all other consequences arising from an economy's general development which in their totality, and according to a study of the CEPE of the UN, exacerbate regional income disparities in less developed countries.

In the EEC, different policy measures are implemented to transfer income directly into mountain areas and into other less-favoured regions. In irrigated areas, some countries have adopted a measure which is related to farming enterprises. This is the case of Spain and Mexico, where the Governments have expropriated parts of large estates and financed some of the costs incurred. By so doing, while the goal of greater equity is pursued via the distribution of the benefits from irrigation, higher efficiency is obtained by the reduction in the size of large estates.

One may also wonder whether other measures would be available. An example would be the adoption of price differentials with the aim of reducing the price of those commodities produced in areas which are able to reap the greater benefits from the development of their agriculture. Another possibility might be the transfer of these benefits to the government *via* the levy of a land-tax. Could other measures be devised? Would problems be encountered in their administration? These are some questions which I think can be raised in connection with the paper of which Dr. Just has provided us with a fine exposition.

GENERAL DISCUSSION* – RAPPORTEUR: ERIC MONKE

Contributors to discussion of the Hayami paper pointed out that the Ricardian approach to growth and distribution was not appropriate for all cases of agricultural development. The European case provides a counter example, where low population growth rates and extreme inequality prevailed in the presence of significant rates of economic growth. Other contributors identified sources of improved income distribution additional to the rightward shift in labour demand induced by new technologies. Human capital investment was suggested as a supply-side approach, which would raise labour wages *via* increases in worker productivity. Hayami's assertion that increased food prices favoured only large farmers was questioned. Increasing prices may lead to increased wage rates if labour supplies are limited since increased output prices will increase the value marginal product of labour, and thus shift the demand curve for labour rightward. Regarding the use of tractors, it was stated that they may be land-saving when they facilitate multiple cropping.

Discussion of the Just/Rausser/Zilderman paper questioned the viability of empirical estimation of the model. Difficulties in the process of preference identification were suggested as barriers to the estimation of an individual utility function. Additional problems were the requirement of the model that every individual utility function be estimated, and the derivations of a deterministic basis for the comparison of utilities across individuals, which is necessary to the valuation of equity effects. An advantage seen in

*Papers by Hayami and Just, Rausser and Zilderman.

the model was the incorporation of attitudinal variables, such as risk. Differences in attitudes towards risk may be a partial explanation of income distribution.

Participants in the discussion included H. von Witzte, M. G. Chandrakanth, Adolf Weber, H. M. G. Herath and H. L. Chawla.