A model of income distribution by size-class with application to the results of technical change

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A model of income distribution by size-class with
application to the results of technical change

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Robert Walter Crown

A Dissertation Submitted to the
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I. INTRODUCTION

A change in technology invariably leads to a change in the absolute and relative levels of living of participants in an economy. In the United States, for example, technical change embodied in machinery and chemicals has led (when conditioned by market prices and producers' strategies) to increased use of these factors in the agricultural sector over, at least, the past 50 years. The increased use has contributed to severe structural readjustment in the sector with respect to farm numbers, farm size and input mix. In turn, this has led to a general depression of rural-family incomes relative to urban incomes, and a widening of the income disparity within the sector.\(^1\) A similarly-generated problem of growing inequity in income distribution has emerged in Canadian agriculture.\(^2\)

Moreover, this general phenomena is not limited to agriculture alone. Lave\(^3\) reviews a considerable literature which traces the incidence of technical innovation and its diffusion


through to an impact on firm size, firm numbers, and the distribution of income among factors of production in manufacturing industries as well as service trades. He reports results which indicate tendencies similar to those in agriculture—declining firm numbers, increasing size of survivor firms, and realignment of factor shares.

Recent dramatic changes in the agricultural technology relating seeds, fertilizer and water to the production of wheat and rice (the green revolution) in Asia have set in motion forces leading to the restructuring of agriculture. In that continent, as well as in North America, an equity problem has emerged with respect to the distribution of the benefits of the new technology, with attendant social and political repercussions.

In India, as an example, the introduction of H.Y.V.'s has led to a concentration of land under the direct management of former landlords and owners, the removal of traditional tenants, and the formation of new tenancy arrangements in which large landowners acquire land from small landowners. In addition, there has been a growing desire to substitute machinery for labor, even though labor has been in general plentiful (but scarce in peak seasons) and seasonally underemployed. This has developed as farm managers attempt to ensure a certain source of power at critical times in the production process and to acquire power sources that do not attempt to exploit a
potential shortage situation by demanding wages rates in excess of productivity (as labor has attempted to).¹

A situation thus seems to be emerging in India, in which an already inequitable distribution of income will become even less equitably distributed, in spite of the advent of a technical change with the power to improve it.² If current socio-political structures survive, institutions continue their usual operational practices, and government continues to implement policy through established instruments (that is, without qualitative economic policy change), Gotsch³ predicts,

¹See Francine R. Frankel, India's Green Revolution: Economic Gains and Political Costs (Princeton: Princeton University Press, 1971). Frankel considers the impacts of the green revolution in both wheat and rice-growing regions of India, and relates the changes in factor shares, tenancy, and so on to the political rise of communistic groups, pressing for equality of incomes through equality of resource ownership.

²Bruce F. Johnston and John Cownie, "The Seed-Fertilizer Revolution and Labor Force Absorption," Amer. Econ. Review, LIX, 569-82 (September, 1969). They argue that the green revolution can be viewed as labor using, with the implication that landless laborers in rural areas can gain through higher wages, ceteris paribus.

³Carl H. Gotsch, "Technical Change and the Distribution of Income In Rural Areas," Amer. Journ. of Agric. Econ., LIV, 326-41 (May, 1972). The model developed there is qualitatively stated, but relates social-state considerations and hypothesis concerning likely actions by individuals in the political arena to the redistribution of income over time. The assumptions behind the prediction are that the green revolution is a simple, divisible and labor-using technical change; that the initial land distribution is uneven; that the institutional setting is initially centralized, and that social structure is hierarchical. These assumptions appear reasonable for India, even though Gotsch was considering the phenomenon in Pakistan.
qualitatively

"The likely pattern (of future income distribution) would involve small farmers becoming better off relative to their previous position but worse off relative to their larger neighbors."\(^1\)

Similar tendencies appear likely throughout the less developed world.\(^2\)

A problem of inequity resulting from technical change has been seen as a general expectation in economic life, with the result that attempts to predict the income redistribution impacts of specific changes have earned considerable attention in theoretical and applied literature. A review of some of this literature follows in a subsequent section. The literature appears, however, to emphasize the impacts of technical change as revealed in changing factor service prices and levels of employment (that is, in changing factor shares. But a simple demonstration shows that even full knowledge of the movement of factor shares, only weakly suggests the direction and extent of changes in individual incomes (the size-distribution of income).

\(^1\)Gotsch, "Technical Change and the Distribution...", p. 339.

\(^2\)See a more general review in Donald B. Keesing, Causes and Implications of Growing Inequality of Income Within Developing Countries, Memorandum 127 (Stanford: Research Center in Economic Growth, Stanford University, February, 1972). Keesing argues that policy action will be the only means of reducing income disparities in LDC's since forces are at work that widen disparities, time can only accentuate the disparities, and decentralized decision-making is ineffective in the face of economy-wide forces.
A. Purpose and Objectives of This Study

The purpose of this study is to develop and illustrate the use of a model for the prediction of the likely impacts of technical change at the individual's income level. The model is intended to yield a quantitative measurement of the direction and extent of the change in relative size-distribution of income, and so indicate the possible emergence of a growing, continuing, or declining equity problem directly. The basis of the model will be an optimization technique so that predictions will be internally consistent.¹

The model should provide two additional outputs: first, a basis for estimating the changes in relative factor shares; secondly, a framework for experimentation with programs aimed at redistributing income among individuals through policy manipulation.

The emphasis on the individual as distinct from the factor services he sells is maintained in an attempt to provide a model for the analysis of socio-economic phenomena. It is, in

¹A discussion of projections made in a consistency framework is contained in Erik Thorbecke and Jati K. Sengupta, "A Consistency Framework for Employment, Output, and Income Distribution Projections Applied to Columbia" (paper presented to the Development Research Center, International Bank for Reconstruction and Development, Washington, D.C. 1972). The authors use the input-output concept of a consistency framework, but the constrained optimization technique also falls within the definition of "consistency".
the final analysis, individuals who perceive injustices, form judgements and feel motivation, riot and overthrow established governments, not abstract factors of production at aggregated levels. The Marxian assumption of a pure laborer, capitalist or rentier, that is an assumption of a one-factor-man, may actually reflect the true situation in one society or other, but a generally applicable model for the analysis of impacts of technical change should not preclude the possibility that the Marxian view is oversimplified.

Some of the more significant assumptions in the construction and application of the model will include:

(a) the assumption that income (appropriately defined) is a reasonable proxy for wellbeing, so that analytic results with respect to the distribution of income can be easily interpreted as results for welfare distribution;

(b) the assumption that socio-political interactions are subsumed in the behavioural relationships used;

(c) the assumption that a consistent aggregation of individuals into classes is possible and successfully done, and
(d) the assumption that for all practical purposes, technical change is embodied in factors of production.¹

¹The concept of disembodied technical change (that is a change that enters the economy free of a medium of transfer, such as a costless reorganization of production processes) persists in economic theory, as does the notion that it can have neutral impacts on relative factor productivities. Jorgenson, however, argues that "...there is a one-to-one correspondance between the indices of total factor productivity and the errors in the price of investment goods that can make the rate of growth in measured total factor productivity equal to zero. In view of this correspondance, one can never distinguish a given rate of growth in total factor productivity from a corresponding rate of growth in the error in measurement of the price of investment goods." [D. W. Jorgenson, "The Embodiment Hypothesis," Journal of Political Economy, LXXIV, 1-17 (February, 1966)]. Solow has made similar claims: "Improvements in technology affect output only to the extent that they are carried into practice either by net capital formation or by replacement of old-fashioned equipment by the latest models with the consequent shift in the distribution of equipment by date of birth." [R. Solow, "Investment and Technical Progress" in Mathematical Models in Social Sciences, ed. by K. J. Arrow, S. Karlin, and P. Suppes (Stanford: Stanford University Press, 1959) p. 91.]

The origins of the disembodiment concept are traced to Hicks. Early definitions of the embodiment concept are traced to Harrod and Robinson (who assumed that technical change entered as an improvement in the efficiency of the labor force using the same capital stock). Allen reviews these earlier developments in R. G. D. Allen, Macro-Economic Theory: A Mathematical Treatment (London: St. Martin's Press, 1968), chapter 13.

Heady viewed technical change as embodied (implicitly) when he defined technical change as being either mechanical or biological. A mechanical innovation was seen as one that changes the desire of the operator to substitute capital for labor (although this does not mean that labor would be unemployed), while a biological innovation simply changed plant physiology. But these biological changes usually require a change in the relative intensities of factor inputs, so that they are qualitatively different from neutral technical changes. [Earl O. Heady, (footnote continued on following page)
B. Prediction and Measurement of Impacts on Income Distribution

To date, the most common method for gauging the impacts of technical change on income distribution has been through movements in relative factor shares under the impetus of the innovation. Factor share analysis, of functional income distribution study, has come to occupy the central position in the overall consideration of income distribution\(^1\), and has come to have a theoretical life of its own. Spacial and sectoral income distribution has received some attention\(^2\) but research in these areas has been largely empirical, and has relied largely on factor share movements to explain observed change.

(footnote continued from previous page) "Basic Economic and Welfare Aspects of Farm Technological Advance," Journal of Farm Economics, XXXI, 293-316 (May, 1949)].

\(^1\) In addition to text books on economic theory, the emphasis is evident in scholarly works such as: Martin Bronfenbrenner, *Income Distribution Theory* (Chicago: Aldine-Atherton Press, 1971) and Lester B. Lave, *Technical Change, Its Conception and Measurement* (Englewood Cliffs: Prentice-Hall 1966).

1. Theoretical considerations

Functional income distribution theory depends on the specification of an aggregate production function. The function can be quantified or not depending on the purpose of the study using it. The important point is that the production function specified is generally assumed to be revealed, or, in effect, an ex post entity.

As an ex post phenomenon, the aggregate production function exists in the context of a set of factor and output prices, and a set of approximate quantities of factor services employed.\(^1\) Thus the parameters exist that allow for the specification of the point elasticity of production namely: the marginal products of the various factors employed at equilibrium levels, the quantities employed, and the prices at which the inputs were employed. Technical changes can thus be observed as changes in the elasticity of production (through change in relative factor productivities, prices, and employed quantities) and changes in the input mix.

\(^{1}\)Conceptually, the ex post production function might be viewed as being the aggregation of the various firm equilibrium positions; as if the economy had found a state of equilibrium such as that depicted in models of production and exchange. See, for example, the systems described in Robert E. Kuenne, The Theory of General Economic Equilibrium (Princeton: Princeton University Press, 1963) chapters 2, 3; or Bent Hansen, A Survey of General Equilibrium Systems (New York: McGraw-Hill, 1970) chapters 2, 3.
Several theorems have been developed that relate the changes in elasticity of production and factor mix to the redistribution of income among factors. These theorems serve to predict the change in relative factor shares following innovation.\(^1\) They can be briefly stated as follows:

1) If a technical change is factor saving, ceteris paribus, the share of income accruing to that factor declines. (In a two factor case, this means that a labor-saving or capital-augmenting technical change has the effect of reducing labor's share).

2) If a technical change increases the ease of substituting factors for each other (that is, if it raises the value of the elasticity of substitution) relative factor shares will move in favor of the factor whose supply is rising. Conversely, if the technical change reduces the ease of substitution, the factor experiencing growth would lose relative position. This would follow since rising supply of one factor would tend to reduce per-unit return if employment prospects were not also growing, while the factor in relatively fixed supply would simply retain or experience rising per-unit returns.\(^2\)

\(^1\) For proof of the theorems, see Murry Brown, On the Theory and Measurement of Technical Change (Cambridge: Cambridge University Press, 1966) chapter 12.

\(^2\) Brown, On the Theory..., pp. 55-56.
3) With an elasticity of substitution less than unity, a factor experiencing increased supply relative to other factors would lose relative share, but with the elasticity of substitution in excess of unity, a relatively growing factor gains relative income position.\(^1\)

With these theorems, and with quantitative measures of the elasticity of substitution and the factor proportions, the impact of technical change on factor shares can be predicted. The question is, however, to specify and quantify an aggregate production function to get the quantitative measurements needed.

2. Quantifying aggregate production functions

Three methodological thrusts have been made towards specifying and quantifying aggregate production functions; the major differences in the methods being the a priori choice of the functional form.\(^2\)

The Cobb-Douglas form of the function has been widely used for analysing changes in income distribution. Indeed, it was the intention of the inventors of the form to study the

\(^1\)If a Cobb-Douglas production function were assumed so that the elasticity of substitution were unity, changes in factor supply would not influence relative factor shares, since the change in factor use would be equal to the percent change in relative prices.

\(^2\)Strictly speaking, there are only two forms of the production function considered, while a third approach subsumes the specified production function. None of the vast literature on forms and quantification of firm-level production functions is considered here.
relationship between the share accruing to factors of production and their marginal products.\(^1\) With later developments, the initial restrictions that the form conform only to constant returns to scale, have been relaxed. However, the Cobb-Douglas function invariably yields elasticity of substitution equal to unity regardless of the scale economies involved.\(^2\) Nevertheless, the form lends itself well to theoretical considerations, and can be used to estimate the relative factor shares directly (as the ratios of the elasticities of production\(^3\)).

The recent invention of the Constant Elasticity of Substitution production function (claimed by two sets of authors\(^4\)), permitted the estimation of non-unity elasticities of substitution, in addition to yielding all of the properties of the Cobb-Douglas function, useful in the analysis of factor

\(^1\)The work of Paul Douglas and other innovators in the field of factor share analysis is given in Brown, On The Theory.... A synthesis of the literature cast in the Cobb-Douglas framework is also given in chapter 8.

\(^2\)Proof of this point is found in Brown, On The Theory..., p. 35.

\(^3\)Proof of this and other properties of the Cobb-Douglas production function are found in Brown, On The Theory..., Chapter 3.

share change under technical advance. The functional form is, however, difficult to quantify, owing to the interdependencies of the elements comprising the parameters. A "two-stage" fitting procedure is required, which detracts from the usefulness of the form in applied analysis.¹ Further, the function is generally not specified for more than two classes of input. Even so, economists have found the form useful.² In addition, the theoretical promise of the functional form has encouraged several efforts to generalize it to more classes of input,³ and to quantify the multi-input forms.⁴

A third distinct methodology for the study of technical change and its impacts on factor shares has avoided the problem of functional-form specification altogether. Mathematical

¹Brown, On The Theory..., cites three methods of fitting the function all with the same difficulty.


Theorems have been developed that show a one-to-one correspondence between specified and quantified cost functions and the unspecified production functions which serve as their basis. In this methodology, only the cost or profit functions of the firm are specified, with the demands for inputs derived directly from these (rather than from production functions). The estimated demand functions provide the coefficients which yield the elasticities of substitution between factors directly. To some extent, this process simply substitutes the difficulty of specifying and quantifying cost functions for those associated with production functions. The process does, however, avoid the need to assume profit maximization as a producer motivation; an assumption that is usually made when deriving input-demand and commodity-supply functions from production functions.

In summary, then, there has been considerable theoretical and quantitative study of income distribution as it is reflected in factor share movements. The question posed in this study,

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however, is whether knowledge of changing relative factor shares gives reliable guidance if concern is with the changes in individuals' relative incomes.

3. Factor shares and individual's income

Some doubt can be cast on the power of factor share analysis as a basis for drawing inferences for individual's income as a result of a brief demonstration. Let there be 3 individuals and 3 factors. The income of an individual \( Y_j \) is the summed product of the \( i \) factor service rates \( r^i \)'s, and the quantities of services sold \( a^i \)'s. This is shown in Equation 1.1.\(^1\) The factor share \( S_i \) is the specific factor service rate times the sum of the services sold by all \( j \) persons, shown in Equation 1.2.

\[
1.1) \quad Y_j = \sum_i r_i a_{ij}
\]

\[
1.2) \quad S_i = r_i \sum_j a_{ij}
\]

The relative factor share of a factor with respect to another would be the ratio of "S's", and the relative income of one family with respect to another is the ratio of "Y's".

\(^1\)This assumes that the factor receives its marginal value product as the rate of return per unit.
In the expository example, the factor share of factor 1 relative to factor 2 is shown in Equation 1.3

\[ \frac{S_1}{S_2} = \frac{r_1(a_{11} + a_{12} + a_{13})}{r_2(a_{21} + a_{22} + a_{23})} \]

The income position of individual 1 relative to individual 2 is shown in Equation 1.4

\[ \frac{Y_1}{Y_2} = \frac{(r_1a_{11} + r_2a_{21} + r_3a_{31})}{(r_1a_{12} + r_2a_{22} + r_3a_{32})} \]

For a change on \( S_1/S_2 \) to imply the exact direction and extent of change in \( Y_1/Y_2 \), regardless of whether the initial change in factor shares was the result of price movement, quantity movement, or a combination, only \( a_{11} \) and \( a_{22} \) can be non-zero. This is comparable to a simplified case in which each individual sells one and only one factor service.

For a change in \( S_1/S_2 \) to imply the direction of the change of \( Y_1/Y_2 \), but not the extent, the income earned in market 1 by individual 1 would have to dominate all other contributing income streams as a whole, as shown in Equation 1.5

\[ r_1a_{11} > (r_2a_{21} + r_3a_{31}) \]

A similar state would be demanded for individual 2; that is income from factor 2 would have to dominate his income.
If these conditions were not met there are only weak inferences to be drawn for individuals from factor share movements.

C. Plan of the Study

A model is developed in Chapter II that directly relates technical change to the distribution of income among individuals (and groups of individuals). It does not depend on prior knowledge of factor share movements; rather it is based on a hypothesized system through which it is supposed that an individual satisfies his welfare needs as a participant in an economy.

Subsequent chapters, II and III, quantify the model and demonstrate its use in the analysis of the impacts of technical change in a district agricultural economy of India. Chapter V contains suggestions for and illustrates introductory use of the model in further quantitative policy research.
The development of the model begins with the definition of a simple system, depicting the behavior of an individual as he attempts to satisfy his welfare needs as a participant in an economy. His participation involves his selling factor services, consuming goods and services (including the service flows derived from his accumulated stock of consumer durables), patronizing public goods and experiencing externalities. His preference function is subsumed in the analysis, but the system is not fully positive since the parameters do not depict the quantitatively revealed behavior of a given individual or group. Factor service markets are also assumed to be present, but they are not specified.

The impact of a technical change for an individual can be viewed in this system. Further, it becomes clear, that several of the system's arguments are (or could be) policy instruments. This is consistent with the view that whatever the "natural" impact of technical change for the individual, there is opportunity for governments to modify it; likewise it is consistent with the view that policy decisions can have roughly the same impact on individual wellbeing as natural technical
changes.\(^1\)

However, the problems associated with changing technology, are more frequently stated in terms of who are the relative "gainers" and "losers", rather than in terms of the absolute change in any given individual's welfare status. The model to evaluate this differentiated impact of technical change is composed of the welfare derivation systems of several individuals'. Technical changes are thus viewed as changing several individual's welfare states simultaneously. A mathematical programming statement of the overall model is given to accommodate the simultaneous nature of the problem, and to ensure consistent projection.

As a prelude to its demonstration in use, the model is restated in terms ammenable to quantification, although the development of the model is expressed in purely theoretical terms.

A. Technical Change and Individual Wellbeing

In an abstract framework, not intended for quantification, a given individual (and his family) derive satisfaction, \( W \), in

\(^1\)For an analysis of the impacts of technical change and policy in American agriculture see Luther Tweeten and Dean Schreiner, "Impact of Public Policy and Technical Change on Marginal Farms and on the Non-Farm Rural Population," in Benefits and Burdens of Rural Development, Center for Agricultural and Rural Development (Ames: Iowa State University, 1970) 41-76.
a given period, from a host of factor-service selling activities, consumption activities, and activities of participation in public goods. For the moment, subscripts designating time-period and individual are omitted.

1. A simple model of individual wellbeing

Let column vectors be designated as

\[ C \] - a (ix1) vector of goods and services consumed (flows),

\[ G \] - a (kxl) vector of flows from public goods,

\[ q \] - a (rx1) vector of factor-service flows derived from set of owned resources, \( q^* \),

\[ I(t-m) \] - a (jxl) vector of possible current consumption flows from stocks of consumer durables of average age "m",

\[ q^* \] - a (j*xl) vector of possible investment goods, (stocks) including human capital and consumer durables which could be acquired in the current time. It is also the vector of currently owned capital stock from which \( q \) and \( I(t-m) \) flow. \( \Delta q^* \) is a vector of investment, that is a change in the capital stock.

\[ Tr \] - a (sxl) vector of income flows as transfer payments.

Let row vectors be designated as

\[ \alpha \] - a (lxi) vector of marginal propensities to derive utility from the goods and service flows consumed,
$\alpha^*$ - a $(l \times k)$ vector of marginal propensities to derive utility from public good flows,

$\gamma$ - a $(l \times i)$ vector of marginal propensities to consume out of current income (where income has both a permanent and transitory component),

$\gamma^*$ - a $(l \times i)$ vector or marginal propensities to consume out of transfer payments. $\gamma^*$ would differ from $\gamma$ in that it would be heavily weighted towards necessity items, with small magnitudes for the items that the individual views as luxuries,

$p$ - a $(l \times r)$ vector of factor-service prices received net of taxes, so that $p_r = \bar{p}_r (1 - T_x^r)$. ($\bar{p}_r$ is the unit price received and $T_x^r$ is the unit tax on factor "r".) The elements could be viewed as fixed for the individual if he was viewed as being a perfect competitor in factor service markets, or be linked with the vector $q$ so that both $p$ and $q$ were simultaneously determined. For convenience, however, let $p$ be a set of given constants for the individual.

$\eta$ - a $(l \times j)$ vector of marginal propensities to consume out of the permanent income flows from consumer durables,
\( \xi \) - a \((l \times s)\) vector of units or zeros, depending upon which forms of transfer payment the individual receives. A vector of zeros indicates that the individual receives no transfer payments. In a more elaborate scheme, there could be a set of conditional logic specified that linked the levels of \( p, q, \) and \( Tr \) through the vector \( \xi \). Alternatively, a vector \( \xi^* \) could be specified the elements of which would vary as the levels of \( Y_c \) varied to different degrees below target levels. However, the simpler specification is retained here for convenience.

\( \delta \) - a \((l \times j^*)\) vector of marginal propensities to spend on capital stock items, \( q^* \) including human capital and consumer durables.

The scalars in the system are.

\( W \) - the level of utility experienced by the individual and his family

\( Y_c \) - income available for current consumption

\( Y \) - total income including permanent and transitory components

\( A \) - amount of income allocated to purchase capital stock items

\( Tr \) - amount of transfer payment income received
E - a factor which increases or decreases current utility by virtue of the individual's experiencing external effects from his community.

Using these definitions, Equation 2.1 shows the individual deriving utility from consumed goods and services, public goods and externalities. Equation 2.2 shows the individual's consuming out of currently disposable income and transfer payments. Equation 2.3 indicates the allocation of total income between current consumption and re-investment. Equation 2.4 defines the allocation for re-investment, as a function of income. Equation 2.5 shows income as a flow derived from the current sale of factor services and from consumer durables, and Equation 2.6 defines transfer payment income as being derived from participation in possible welfare programs. A simplified form of the system expressing W in terms of the activities of the individual is given as Equation 2.7. It is derived after substitution\(^1\) and simplification.

2.1) \( W = \alpha C + \alpha^* G + E \)
2.2) \( C = \gamma' Y_C + \gamma^* \overline{Tr} \)
2.3) \( Y_C = Y - A \)
2.4) \( A = \sum \Delta q^*_j; \Delta q^* = \delta' Y \)

\(^1\) Substitute from Equations 2.4 and 2.5 into 2.3; 2.3 and 2.6 into 2.2; 2.2 into 2.1.
2.5) \( Y = pq + \eta I_{(t-m)} \)

2.6) \( \bar{Tr} = \xi Tr \)

2.7) \( W = \alpha \gamma'pq + \alpha \gamma'\eta I_{(t-m)} + \alpha \gamma'\xi Tr + \alpha G + E - \alpha \gamma'A \)

The system subsumes a preference function whose parameters would be the rate of deriving utility from flows of goods and services, \( \alpha \); the intertemporal consumption preferences in \( \delta \); and the rates of possible disutility from offering factor services. In its reduced form, the model shows that the individual might derive utility at different rates from different sources of income, depending on how he consumed out of different income flows.\(^1\) Further, the model allows the individual to view income flows as non-perfect substitutes for each other in satisfying welfare needs [since it is unlikely that \( \alpha \gamma'p = \alpha \gamma'\eta = \alpha \gamma'\xi \)].

2. The impact of technical change on individual wellbeing

An abstract technical change will immediately affect the individual's welfare by changing the relative factor-service

\(^1\)Recent evidence indicates that there is some support for the hypothesis that individuals demonstrate different consumption behavior when spending income derived from labor wages, capital lending or permanent sources. Robert Holbrook and Frank Stafford, *The Propensity to Consume Separate Types of Income: A Generalized Permanent Income Hypothesis*, Michigan Research Paper 1, University of Michigan (Ann Arbor: University of Michigan, May 1968).
productivities, and so the relative prices paid. The individual will gain income to the extent that he sells the favored factor-service and lose income to the extent that he sells the other factor services. He will also gain to the extent that he can sell more of some factor services (if he has them to sell) and lose to the extent that factor substitution in production reduces demands for factor services he might have sold. The resulting change in welfare will be the change in income flows from different sources modified by the individual's consumption out of different income flows and the utility derived from the goods and services so consumed.

Over time, the individual's sustained welfare would change to the extent that he was encouraged to adjust his asset holdings (that is, make adjustments in $q^*\)$. These portfolio changes would be conditioned, however, by the individual's intertemporal consumption desires. Changes in the tax structure could alter the factor prices received for the factor service sales, and transfer payment programs could supplement income if instituted. The welfare derived from these changes would, again, be modified by the preferences of the individual for the goods and services these income flows support.

1 Added constraints to capital stock adjustment not specified but presumably influencing the vector $\delta$, are constraints imposed by law, by the degree of divisibility in the asset, or by the price per salable unit of asset in relation to individual's debt capacity and income.
Variation in government offerings of public goods, or welfare programs would also modify individual wellbeing.

If the individual owned only one type of capital and offered only one factor service for sale, it would be relatively simple to predict the direction (and possibly the extent) of the change in his absolute level of wellbeing. The change he experienced following the technical change, would be that experienced by the factor he sold. But if he sells more than one factor service, the net change in income (and thus, welfare) would be known only after an empirical investigation of the individual's situation before and after the technical change. Moreover, even if the individual initially sold only one type of factor service, the possibility that he could alter his capital stock and begin to sell other factor services means that empirical investigation would be needed to indicate the changes in his income and welfare overtime.

B. Technical Change and Relative Wellbeing

It would be feasible (assuming that a measurement of welfare were available) to develop a reduced form equation like Equation 2.7 for each participant in the economy to actually work out the gains or losses to each, as technology changed. However, the cost of such universal inclusion of individuals would be large considering the possibility of gaining similar
estimates of impact (with only slightly less probability of being "correct") by considering near-homogeneous groups instead.

1. Aggregation

A consistent aggregation could be made by specifying class marks so as to minimize the variance within a group and maximize the differences between groups. Moreover, the bounds of consistency depend to a large extent, on the problem to be analysed, and the intended use of the analysis. If concern was with the impacts of technical change (or any change for that matter) on individuals with different levels of income and welfare, aggregation would tend to be consistent if low income persons were aggregated together regardless of the factor services sold or assets held. In the present analysis it is assumed that individuals have been grouped into consistent classes with the object of highlighting the similarities in their current income levels (where current indicates the state before the technical change).

Let the groups of families formed in the aggregation sell their factor services and buy the goods and services from which they derive utility, in markets that are linked through effective arbitrage. Further, let all participants buy new productive assets in capital stock markets that are similarly linked. Therefore, relative price movements are the same for all, even though absolute prices may differ owing to differences in monopoly or monopsony power. If all families are in perfect competition, even the absolute prices would be the same. All individuals would be faced with changes in factor demands and changing relative real factor-service prices simultaneously. A model now needs to be stated for measuring the differential impacts of technological change on the welfare positions of grouped individuals, when these changes simultaneously confront all groups.

2. Model of relative group wellbeing

Assume that all factor owners (as represented in their groups) attempt to maximize the value of their perceived welfare functions subject to constraints imposed by their own stock of capital, their tastes and preferences, the perceived relative prices of commodities and prices of factors services sold, and the activities of others buying and selling in the same markets. In a sense, the groups are in competition for the welfare that the economy has to offer. The problem of several groups attempting to simultaneously maximize their own
welfare under these conditions then appears ammenable to analysis in a programming framework.

The objective function of the economy when depicted as a program would be the simple unit-weighted sum of "n" group's welfare.¹ Being unit-weighted, an increase in welfare would be of equal value, regardless of the group that experienced the gain. This would be consistent with a notion that the economy under laissez-faire does not set a priori preferences for the wellbeing of specified groups but rather is impartially with respect to individuals and groups of them. An assumption that group welfare functions are independent would not be vital in this model since interdependencies could be included in specification of constraints.

Assuming "n" groups in the economy, Equation set 2.8 depicts the welfare maximization problem stated from the resource-owner's viewpoint.²

¹If there are "1" individuals in group "n", the welfare of group "n", \( W_n \), would be the sum of individual welfares, \( W_n = \sum \tilde{W}_{1n} \), where \( \tilde{W}_1 \) is given in Equation 2.7 (recalling that subscripts had been omitted there).

²This is a simplification for the sake of exposition here. In an enlarged study one could include a detailed specification of the production side, linking this with the distribution of resources among groups of individuals so that the variables assumed to be exogenous in this statement would be endogenized.
Maximize: \[ Z = c'W \]
\[ c = (1, 1, \ldots, 1) \]
\[ W = (W_1, W_2, \ldots, W_n) \]

where: \[ W_n = \rho_n z_n \]
\[ \rho_n = (\alpha_n, \alpha_n^*) \]

subject to: \[ 0z \leq R \]
\[ z_n = (z_1, z_2, \ldots, z_n) \] for the nth group

The variables in the model are now described briefly. Parenthetically, the transformation between the nth classes' activities, \( z_n \), and \( W_n \), the nth classes' welfare, is included simply to emphasize the point that the economy would operate so as to impartially and impersonally maximize total welfare, \( W \) (hence the vector of units placed where prices enter a standard program, \( c \)). In fact, a more operational statement would be that the economy seeks to maximize the welfare value of all the activities of all the groups simultaneously, that is, \( Z = \rho z \) where \( \rho = (\rho_1, \rho_2, \ldots, \rho_n) \).

a) Activities, \( z \): The column vector, \( z \), is a vector of class-specific activity vectors such that \( z = (z_1, z_2, \ldots, z_n) \). For the nth class, \( z_n = (q_n, I(t-m)_n, Tr_n, G_n) \); that is, it is a vector of inflow activities contributing to the individual's welfare as defined for Equation 2.7. There are \( \Sigma \) \( n \) \( x_n + j_n + s_n + k_n \) activities in \( Z \).

b) Resource constraints, \( R \): The "right-hand-side", \( R \), is a column vector of class-specific resource vectors, \( q^*_n \), and includes two columns \( Tr^* \) and \( G^* \) depicting the stock from which
the s transfer payments and k public goods are derived through public policy. \( q^* \) is the stock from which the activities of factor-service sale \( q_n \) and consumption of part of the individual's permanent income \( I_{(t-m)n} \) are derived. There are \( j_n^* \) entries in each \( R_n \) sub-vector. The inclusion of resources of the economy generating transfer and public good flows as separate stock vectors indicates that all individuals would draw on the common flows \( T_r \) and \( G \), so that there would be an element of competition between groups for the scarce flows available. There are conceptually, as many as \( (s+k) \) such economy-wide resources.

The vector \( R \) has a maximum of \( \Sigma j_n^* + s + k \) entries. If each group owns the same generic type of resource, there is a maximum of \( nj^* + s + k \) elements.

c) Matrix of input-output coefficients \( \phi \): The matrix of input-output coefficients, \( \phi \), will have a dimension of

\[
\Sigma j_n^* + s + k \text{ by } \Sigma (i+s)_n; \text{ or, which is the same thing, } \Sigma j_n^* + s + k \text{ by } \Sigma (r+j+s+k)_n.  
\]

The internal structure

\[
\Sigma j_n^* + s + k \text{ by } \Sigma (r+j+s+k)_n.  
\]

\[\text{Equation 2.7 shows that since the income flows are spent on the acquisition of consumer goods and services, from which utility is derived, } (i+s)_n = (r+j+k+s)_n. \text{ If each class held generically identical resources and consumed a generically standard set of goods and services, the dimensions of } \phi \text{ would be } nj^* + s + k \text{ by } n(i+s).\]
of $\varnothing$ will vary, depending on the assumptions that are made concerning the allocation of income to various alternate consumption possibilities. In general, the matrix will have a block-diagonal configuration, as illustrated in Figure 2.1. The figure is considerably simplified in its detail, employing the notations of the algebraic development in a preceding section of this chapter.

In the unlikely event however, that there was one-to-one relationship between income flows of different types and items of current consumption, $\varnothing$ would become perfectly diagonal (except for the coefficients transforming flows from $T_r^*$ and $G^*$ into class-specific utility).

3. Impacts of technical change on relative wellbeing

A set of impacts result from technical change that are qualitatively similar to those discussed in the context of the individual. But in the present case, the impacts are experienced by "n" groups simultaneously so that a change in the absolute level of wellbeing of any group represents a change in relative wellbeing between groups.

The immediate impact of the technical change would be to change relative factor productivities, with a resultant change in relative factor-service prices (assuming markets that are reasonably free of imperfections). In the context of equation set 2.8, this would be represented by a change in some of the
Figure 2.1 Configuration of Input-Output Coefficients, $\phi$, With Resource Constraints and Type of Limit.
elements of $\emptyset$; namely the factor prices, $p$, for each group of participants that sell the factor service involved. An alternate interpretation of the impact of change would be that it changes the relative effective availability of capital stock items. This represents a change in the structure of $R$.

If more than one group of individuals sells the factor services involved, or own the items of capital influenced by the technical change, the resulting distribution of welfare among groups would be difficult to determine, except through quantitative experimentation.\(^1\) In the event that each group sold one and only one factor service, and owned one and only one type of capital, however, relative group welfare would change in the direction and extent of changed factor shares.\(^2\)

Over time, the predictability of the relative welfare outcome of technical change would decrease further, even with the assumption of one-factor-groups. In the longer run, individuals in groups could alter the composition of its asset holdings, leading to further restructuring of $R$. With a

\(^1\)This conclusion parallels a standard conclusion in conventional programming; that a change in the optimal mix or levels of activities following a change in resource constraints or technical coefficients is not generally predictable a priori. In the present model, the mix of activities would represent the various activities of the groups, and the levels would be the amounts of utility derived from the activities.

\(^2\)This is the same conclusion stated in Chapter I. Recall that in this case, the one-factor-group assumption would lead to a diagonal matrix.
restructured asset base, the set of alternative activities for the satisfaction of welfare needs could also change (being incorporated into the model by adding or deleting elements in $q_n$, or $I(t-m)n$). Perceived differences in the availability of consumably commodities or services following the technical change could lead individuals to adjust their consumption patterns, which would be reflected in changes in $\rho$, or $\gamma$. Increased or decreased participation in transfer payment programs over time would be reflected in changes in $\xi$.

In this longer run, therefore, in the absence of government policy changes (which would be incorporated in changes in $G^*$ or $Tr^*$) the distribution of welfare among groups would again become a matter for empirical determination.

C. Technical Change and Relative Income

The discussion up to this point has been in terms and relationships that would not generally lend themselves to quantification. Because the determination of the changes caused by technical change appears to be an empirical question however, translation of the model into quantifiable terms is necessary if further analysis is to be considered.

With the assumption that maximizing income\(^1\) is a necessary precondition for maximizing welfare, the system

\(^1\)The appropriate measure of income is discussed in Chapter III.
depicted in Equations 2.1 through 2.7 is reconsidered. Simplifications of the individual's system that would be consistent with the assumption that income precedes welfare attainment would include

a) a removal of the specification of the individual's consumption behavior

b) removal of the specification of the determinants of investment (although in application, amounts allocated for reinvestment would be identified so they are not classified as satisfying current utility needs)

c) removal of the specification of the propensity to participate in public goods, and experience externalities.

The specification of the receipts of transfer payments, would be retained since the individual could still use this form of income to satisfy welfare needs (even though he might not view transfers as perfect substitutes for earned income). However, the value of the individual's (and so a group's) income could be raised indefinitely through transfer payments. Therefore, transfers are included in the revised system under a rule that prevents the payment of transfers except to fill a gap between earned and some pre-determined target income for the group. In a laissez-faire economy, the target income would be zero.

A further assumption is that the value of $\eta$ is estimated by the rental price of the service of the durable good. In
the revised system, therefore, a vector of values received, 
p''', includes the prices, p, received from the sale of factor services and the values of estimated n.

Equation set 2.9 describes the income maximization system for the economy.

Maximize \( A = cY \)  
\[ c = (1, 1, \ldots, 1) \]
\[ Y = (Y_1, Y_2, \ldots, Y_n) \]

where \( Y_n = p''n = n \left( q_n \right) + \xi_nTr_n \) for group "n"

\[ I_{(t-m)n} \]

subject to

\[ 2.9) \quad B \begin{bmatrix} q \\ I_{t-m} \\ Tr \end{bmatrix} \leq \begin{bmatrix} q^* \\ Tr^* \end{bmatrix} \]

\[ Tr_n = 0 \text{ if } p''n < q_n \]
\[ Tr_n = Y_n(\text{target}) - p''n \quad \begin{bmatrix} q_n \\ I_{(t-m)n} \end{bmatrix} \text{ if } p''n \geq q_n \]

\[ q_n \geq 0 \quad I_{(t-m)n} \geq 0 \]
The parameters in the system have been defined in this chapter, with the exception of the matrix of coefficients B. The matrix B is block-diagonal, as was the matrix $\mathcal{C}$. However, the non-zero elements of B would be units throughout, so that the matrix simply serves as a transfer medium for assigning flows of factor-service and transfer payments to the markets in which the groups of individuals participate.

All parameters in equation set 2.9 can be quantified, so that the model in this form could be applied to determine the impacts of technical change on relative income levels of different groups in the economy. If the $n$ groups are formed to highlight the differences in the size of their incomes, the model will show the impacts of technical change on the size-distribution of income.
The desire to consider the welfare of several groups in a simultaneous analysis, to identify the size-distributional impacts of technical change, motivated the use of mathematical programming as a means of stating the problem. This chapter contains the quantification of the size-distribution model stated at the end of the preceding chapter.

A. An Illustrative Economy

The Muzaffar-Nagar district of Uttar Pradesh in India's wheat growing region, experienced the introduction of high yielding varieties in the 1965-66 growing season. This district was not a participant in the planned intensive agricultural development program\(^1\) of the Government of India, so that the introduction and adoption of the new seeds and methods, since then, can be considered as approximating a natural and evolutionary spread of technological change.

The Muzaffar-Nagar district lies in the extreme north-west part of the state, so that it can be considered a primarily wheat-growing region, even though Uttar Pradesh produces as much rice as wheat.

1. The economy in context

In the 1954-57 period, a typical farm in Muzaffar-Nagar district contained 4.16 hectares (about 6 acres) of which 80 percent was irrigated, had a cropping intensity of 137 (a cropping intensity of 100 indicates that one crop per growing season is obtained), and cultivated 71 percent of the land in food crops. These average magnitudes indicate that farms in the district were in the near median position with respect to the 13 districts in other 7 states covered in the original Studies.

In the district, farms generally were operated by families with about 7 members (including permanent servants) who owned 2.5 draught animals and who generally relied on a market for inputs (since there was a relatively high proportion of paid-

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1 The data in this and the following paragraphs are from Government of India, Ministry of Food and Agriculture, Directorate of Economics and Statistics, Farm Management in India (New Delhi, author, 1966). This document contains a synopsis of the findings of the 14 district-wise Government of India, Ministry of Food and Agriculture, Directorate of Economics and Statistics, Studies in the Economics of Farm Management (The Studies) conducted over the years 1954-62 which were based on cost accounting surveys of a representative sample of farms (in a variety of states).
out expenses in cash and kind to total expenses including imputed expenses; 71 percent in Muzaffar-Nagar compared with an all-India high of 82 percent and a low of 35 percent). Farms in the district enjoyed relative prosperity compared to other districts in the 1954-62 years with net incomes in cash and kind of about Rs. 260 per hectare compared with an all-India a high of Rs. 324 and a low of Rs. 64. This represented about 1.94 of the paid-out expenses. As an indication of profitability, farms in the district showed a ratio of output to total expenses (including imputed labor, land and capital costs) of 1.26 compared to a high of 1.41 and a low of 0.25. The district was not the most prosperous, most profitable, or most advanced in India. It was, however, one of the districts in which the coming of the "green revolution" in wheat altered the production structure. The changes are now discussed further.

2. Economic changes over a decade

Over the decade between 1954-57 and 1968-69, that is, between the times that the Muzaffar-Nagar district first came under survey as part of the Studies and a more recent survey, several changes have occurred, the impetus for which can be attributed to the "green revolution" in wheat production. Although average farm size has remained about the same, farm business income has grown considerably on both the per-farm and per-hectare basis. The growth indicated in Table 3.1,
<table>
<thead>
<tr>
<th>Item</th>
<th>54-57&lt;sup&gt;b&lt;/sup&gt;</th>
<th>68-69&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Change&lt;sup&gt;d&lt;/sup&gt;</th>
<th>54-57</th>
<th>68-69</th>
<th>Change&lt;sup&gt;d&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average farm size (hectare)</td>
<td></td>
<td></td>
<td></td>
<td>1.34</td>
<td>1.24</td>
<td>0.93</td>
</tr>
<tr>
<td>Farm size-class (hectares)</td>
<td>1.34</td>
<td>3.08</td>
<td>4.90</td>
<td>6.84</td>
<td>11.17</td>
<td></td>
</tr>
<tr>
<td>Farm business income, Rs.</td>
<td>68-69</td>
<td>1,934.09</td>
<td>2,483.95</td>
<td>2,289.32</td>
<td>2,222.60</td>
<td>2,357.72</td>
</tr>
<tr>
<td>Change per hectare</td>
<td></td>
<td></td>
<td></td>
<td>8.15</td>
<td>12.11</td>
<td>11.44</td>
</tr>
</tbody>
</table>

Table 3.1. Pattern of farm business income<sup>a</sup> by farm size-class, 1954-57 and 1968-69, Muzaffar-Nagar
Farm business income is the value of total output at market prices (received or imputed) less the total paid out expense in cash or kind. In effect it is the return to owned land, owned capital and family labor.


Change is the ratio of 1968-69 estimate to 1954-57 estimate.
is growth in terms of market prices, but real growth is still impressive, even allowing for a general rise in prices of about 68 percent between 1960-61 and 1967-68. In addition, however, there was a general growth in income disparities in farming, both in terms of the gap relative to the families operating the smallest farms (the under 2.02 hectare farms) and the disparity between the farm generated incomes of other farm size-groups.

Some caution should be used in drawing the inference that the growing divergence between the farm business incomes of small and large farm-operating families signals an equal divergence in family welfares. Typically, for small farm operators, at least, some off-farm employment supplements family income which is not included as farm business income. Nevertheless, the divergence exhibited is an indicator of a trend that would be expected to continue, namely, that the income

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2 Government of India, Farm Management..., Appendix Table II (b), p. 99, shows the farm with under 1.01 hectare having about 36 days employment off the holding.
3 A model showing the continued growth in income disparities among farm-operating families as a result of simple profit maximizing behavior and resource acquisition is contained in Uma K. Srivastava, Robert W. Crown and Earl O. Heady, "Green Revolution and Farm Income Distribution," Economic and Political Weekly, VI, No. 52, Review of Agriculture, A-163--A-172 (Bombay: December, 1971).
earned from farming is likely to have an increasingly skewed distribution among farm-operating families, in favor of operators of larger farms.

Changes in resource ownership and employment have occurred simultaneously with the changes in absolute and relative income (see Table 3.2). In the context of the programming framework given in Chapter II, these changes can be viewed as changes in the vector of constraints "R". Although relatively small shifts have occurred with respect to average size of operational holding, the asset value of land has risen dramatically as a result of the increased output potential of the H.Y.V. wheats. This indicates growth in the rental value of land, although "rent" is not explicitly given in the table.

Of equal interest is the change in the structure of employment that has corresponded to the change in land productivity. Employment of family labor on farms has declined for all farm size-classes, on both per-farm and per-hectare bases. In contrast, there has been a large increase in the employment of hired labor per-farm on large farms, with an absolute decline on small farms. Further, on the per-hectare basis, employment of hired labor has increased on larger farms and remained about constant on smaller farms. These tendencies indicate the possibility that labor formerly employed on smaller farms (both family and hired labor) in the 1954-57 period has found some new employment on large farms in the
Table 3.2. Resource employment by farm size-class 1954-57 and 1968-69, Muzaffar-Nagar

<table>
<thead>
<tr>
<th>Item</th>
<th>Farm size-class (hectares)</th>
<th>Under</th>
<th>2.02</th>
<th>-4.03</th>
<th>4.04</th>
<th>-6.05</th>
<th>-8.07</th>
<th>Over</th>
<th>8.09</th>
</tr>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Family labor per</td>
<td>54-57*</td>
<td>457.9</td>
<td>639.4</td>
<td>604.9</td>
<td>904.9</td>
<td>980.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>farm (days)</td>
<td>68-69^</td>
<td>164.0</td>
<td>333.5</td>
<td>357.3</td>
<td>421.6</td>
<td>583.0</td>
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<td></td>
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<tr>
<td>Change</td>
<td>0.36</td>
<td>0.52</td>
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<td>0.60</td>
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<tr>
<td>Family labor per</td>
<td>54-57</td>
<td>431.7</td>
<td>207.6</td>
<td>123.5</td>
<td>132.3</td>
<td>87.7</td>
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<tr>
<td>hectare (days)</td>
<td>68-69</td>
<td>132.2</td>
<td>109.0</td>
<td>72.3</td>
<td>57.6</td>
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<tr>
<td>Change</td>
<td>0.39</td>
<td>0.53</td>
<td>0.59</td>
<td>0.44</td>
<td>0.52</td>
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<tr>
<td>Hired labor per</td>
<td>54-57</td>
<td>33.3</td>
<td>76.5</td>
<td>115.5</td>
<td>164.1</td>
<td>208.5</td>
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<tr>
<td>farm (days)</td>
<td>68-69</td>
<td>18.6</td>
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<td>Hired labor per</td>
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<td>14.7</td>
<td>14.8</td>
<td>14.2</td>
<td>14.3</td>
<td>11.2</td>
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<tr>
<td>hectare (days)</td>
<td>68-69</td>
<td>15.0</td>
<td>19.6</td>
<td>32.0</td>
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<td>2.69</td>
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<td>68-69</td>
<td>1,563.62</td>
<td>2.44</td>
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<tr>
<td>Change</td>
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<td>3.11</td>
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<th>Value (Rs.)</th>
<th>Change</th>
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<td>3.62</td>
</tr>
</tbody>
</table>


^cChange is the ratio of 1968-69 estimate to 1954-57 estimate.
post-green revolution period (assuming a constant or growing labor force). A reasonable view would be that the decreased family labor input simultaneous with increased hired labor input on large farms signals growing leisure-taking or off-farm employment for members of these farm families. As a general tendency, however, there seems to be fewer labor days employed per hectare in the 1968-69 period.

The capital stock per hectare has increased for all farms. This would be consistent with a hypothesis that successful production of H.Y.V. wheats requires a minimum level of new fixed capital (essentially a minimum capital stock regardless of farm size), and that it has been profitab...e for even small-sized farms to make this minimum acquisition. However, there has been a change in the level of capital per hectare on large with respect to small farms over the decade. In the fifties, before the green revolution, it was apparent that the investment per hectare and farm size were inversely related. This indicates that under the technical production function of that day, it required relatively little capital to exhaust that factor's positive marginal value product.¹

¹One hypothesis links the low marginal value of capital to growth in land values over the decade. When capital was at the zero-marginal value point surplus income was used to speculate in land; both in a desire to raise total income (assuming constant returns to scale) and to acquire status, and an inflation-proof savings form. See Profulla C. Sarkar, The Planning of Agriculture in India (Rotterdam: Rotterdam University Press, 1966).
After the change in production possibilities in the mid-sixties, however, it has become increasingly profitable to acquire and employ capital. Further, since larger farms would not be as constrained in their capital acquisitions by income and credit restraints as small farms, they would have added more capital relative to their former positions than small farmers.

In general, therefore, in the largest farms, the 300 percent indicated increase in capital (even allowing for price rises) has occurred simultaneously with a 14 percent increase in land area and a moderate decline in labor input per hectare. For the 6.06-8.07 hectare class, a 300 percent growth in capital per hectare has accompanied a 7 percent increase in average farm size and a 41 percent decline in per-hectare employment. For the 4.04-6.05 hectare class, the 2.02-4.03 hectare class and the under 2.02 hectare class, the increases in capital stock have been less pronounced, with constant or declining average farm size, and a reduction in employment per hectare of 24 percent, 42 percent and 51 percent respectively. Thus there has been a tendency, over the decade, for change to be relatively labor saving (but not necessarily employment reducing).

A model which indicated the general continuance of these tendencies when quantified with reasonably estimated parameters would probably be more believable than one that did not. Auxiliary results and conclusions drawn from a model that was consistent with these tendencies would also be reliable. The
task for the remainder of this chapter is to make a reasonably approximate quantification of the "quantifiable" model presented in Chapter II.

B. The Model As Applied

One convenience of applying the model to an agricultural economy, is that within families and groups of families there are both sales options open for the marketing of factor services outside the family and the possibilities of marketing factor services through home production activities. New production possibilities can, therefore, be explicitly stated as activities, as they might be viewed from resource-owners' standpoint. Further a round of explicit assumptions as to factor productivities, factor service prices and barriers to competition can be avoided.

Data depicting the structure of the economy as it has most recently appeared (1968-69) are used to quantify the initial or "pre-technological-change" model. This is a second-best approach, the most desirable situation being one in which the model is quantified before the technical change actually occurred and re-run after the technical change, when changes in production possibilities, factor availabilities, or selected input-output coefficients indicating the advent of the change are present.
However, the second-best approach is acceptable in an analysis involving the green revolution, since:

a) there is no apparently clear-cut date on which technical change can be said to have occurred; rather, there is a period over which the technical change gradually became accepted and implemented.\(^1\)

b) producer behavior exhibited in the future would probably be based on a set of relative prices, perceptions of profitability, expectations and aspirations common with those that followed the 1966 introduction of H.Y.V.'s therefore, that information from an earlier time would not add to the reliability of predicted behavior.

c) the income distribution is already known for a time in which the technical change was in wide application; that is, the 1968-69 period, so that earlier observations would be redundant.

and

d) as a result of knowing a current structure of the sector and a concurrent income distribution, along with a likely set of producer behavioral relationships, predictions of future income distributions should be possible without resort to data from a more historic past.

This will be the basis of the research strategy in the remainder of this study.

1. **Restatement of the model**

The problem faced in the economy under the assumption that the income of all participants taken together is maximized,

\(^1\)In 1966, only 3,000 of the 12.6 million hectares under wheat cultivation in India were in high yielding varieties. But, by 1968 3 million of the 15 million hectares in wheat were allocated to H.Y.V.'s. The area increased to 6 million out of a possible 16 million hectares by 1970. United States Department of Agriculture, *High Yielding Varieties of Wheat in Developing Countries, ERS-F-322* (Washington, D.C., author, 1972) Table 2, p. 7.
without regard for individuals or specific persons is restated here as equation set 3.1.

Maximize \( A = cY \)

\[ c = (1, 1, \ldots, 1) \]

\[ Y = (Y_1, Y_2, \ldots, Y_n) \]

where \( Y_n = p_n'' \begin{bmatrix} q_n \\ I_{(t-m)n} \end{bmatrix} \) + \( \xi_n \text{Tr}_n \) for the nth group

subject to

\[ 3.1) \quad B \begin{bmatrix} q \\ I_{(t-m)} \\ \text{Tr} \end{bmatrix} \leq \begin{bmatrix} q^* \\ \text{Tr}^* \end{bmatrix} \]

\( \text{Tr}_n = 0 \) if \( p_n'' \begin{bmatrix} q_n \\ I_{(t-m)n} \end{bmatrix} \geq Y_n \) (target)

\( \text{Tr}_n = Y_n \) (target) - \( p_n'' \begin{bmatrix} q_n \\ I_{(t-m)n} \end{bmatrix} \) if \( p_n'' \begin{bmatrix} q_n \\ I_{(t-m)n} \end{bmatrix} < Y_n \) (target)

\( q_n \geq 0 \quad I_{(t-m)n} \geq 0 \)

The model is now respecified in terms appropriate for application to the agricultural economy of Muzaffar-Nagar. Several simplifications are assumed in the redefinition of the variables, however, the essential features of the theoretical model of Chapter II are retained.
a. Basis for aggregation  The problem as stated in equation set 3.1, is defined for "n" groups of individuals; each group formed so as to minimize the differences between the included individuals in an attempt to ensure a consistent aggregation. In this application, the concern is with the impacts of technical change (the advent of the green revolution) on the size distribution of income. Thus income determining variables are used as a basis for drawing class marks. The population of farm families are classified by size of farm holding in the current case both as a convenience (several sources of published data are on the farm-size basis) and in an attempt to draw inferences that are on a basis consistent, with several other policy issues of interest in Indian agriculture. Moreover, the use of the convenient classification by farm size does not invalidate inferences to income size and size-distribution of income changes, since there is a clearly non-negative relationship between the levels of per-hectare income and size of operational holding.\(^1\) The numbers in each class, the class marks, and the average size of holding in each class are given in Table 3.3.

\(^1\)See Table 3.1. Also see Uma K. Srivastava, Vishnuprasad Nagadevara, and Earl O. Heady, "Resource Productivity, Returns to Scale and Farm Size in Indian Agriculture: Some Further Evidence," Australian Journal of Agricultural Economics, (forthcoming) in which the traditional belief in the inverse relationship between returns per hectare and farm size is shown to be no longer a correct conceptualization of agriculture in Uttar Pradesh.
Table 3.3. Distribution of sample used by size-class, Muzaffar-Nagar,\textsuperscript{a} 1968-69

<table>
<thead>
<tr>
<th>Class marks (hectares)</th>
<th>No. of farms</th>
<th>Hectares in class</th>
<th>Average hectarages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 2.02</td>
<td>17</td>
<td>21.09</td>
<td>1.24</td>
</tr>
<tr>
<td>2.02-4.03</td>
<td>33</td>
<td>100.97</td>
<td>3.06</td>
</tr>
<tr>
<td>4.04-6.05</td>
<td>32</td>
<td>158.14</td>
<td>4.94</td>
</tr>
<tr>
<td>6.06-10.0</td>
<td>37</td>
<td>282.24</td>
<td>7.63</td>
</tr>
<tr>
<td>Over 10.0</td>
<td>31</td>
<td>425.81</td>
<td>13.74</td>
</tr>
</tbody>
</table>


b. Activities included In the current example, it is assumed that if income is maximized, the best possible set of preconditions exist for individuals to satisfy their welfare needs. The question now revolves around specifying what activities could yield income of the appropriate type so that individuals can proceed with welfare maximization on their own; that is defining what would constitute $Y_n$. "Appropriate" income for satisfying welfare would be disposable income; that is, income that is already net of the costs of acquiring it. Ignoring several issues that could be raised concerning the
cost of maintaining a man or bullock in physical condition suitable for work, the cost of depreciation and maintenance on owned capital, or capital appreciation of land, income earned in the form of wages, interest and rents from hiring out, leasing out and renting out owner resources could be considered appropriate partial estimators of \( Y_n \). For uniformity, it is assumed that individuals in each size-class have the option of renting out land as if to a common pool, hiring out their labor for use by farms in any of the other size-classes, leasing out movable capital for use by farms in any other size-classes, and hiring out days of bullock power for use by others. Each size-class, therefore, would have thirteen alternative direct factor service selling options open.\(^1\) In terms of the equation set 3.1, the possibility for selling factor services to other farm operators would account for thirteen prices receivable in \( p_n' \) and thirteen possible activities in \( q_n' \).

\(^1\)The inclusion of one option for renting out land, but four options for participation in labor, capital leasing, and bullock markets is assumed because Government of India, Studies...1968-69, shows that typical farm operators in each of the size-classes were paying for hired-in resource services at rates that decreased as average farm size increased. This could reflect differences in monopsony power, directly related to farm size. It shows, further, that for labor, capital, and bullock services, a resource owner could sell factor services at different rates subject to constraints imposed by demand. The rental value of land, in contrast, was uniform throughout the economy, with the rate per hectare being about 10 percent of the per-hectare asset value of land (rent being Rs. 600 per hectare).
In the application, individuals are permitted to market factor services from owned resources through the activity of farming, in competition with outright factor-service sale. The income contribution of this activity however, requires some elaboration. Total receipts (in cash and in kind) from farming would apparently overestimate \( Y_n \) by the amount of paid-out expenses that farming requires. But similarly, profit (the value accruing after all imputed and paid-out costs are deducted from total receipts) would underestimate \( Y_n \) since it would exclude the value of imputed wages to family labor, imputed rent to owned land and imputed returns to owned capital and bullocks which a family could use to purchase items of \( C \) or \( q^* \). The concept of Farm Business Income (F.B.I.) most closely approximates \( Y_n \) for a family (and therefore the group) since it is the return to the family's labor, land, capital, bullocks, and management (estimated as total value of output less paid out expenses). Its use assumes, moreover, that barter for \( C \) and \( q^* \) is as acceptable as cash purchase, since part of the value

\[1\] The model could contain specification of several competing enterprises rather than the one net farming activity included here. With such an expansion, a variety of commodity-oriented policy alternatives could be researched. But for the present, data were not subdivided by enterprise since this was not necessary in considering the measurement of impacts of technical change on family incomes. The use of a single farming activity assumes that farmers have already made their decision concerning the mix of inputs used, the amounts of inputs used, the mix of enterprises followed, and the levels of enterprises followed in accordance with their personal calculus of income maximization.
of F.B.I. (hence \( Y_n \)) would be the value of income-in-kind. Farming would be the fourteenth income-earning activity in \( q_n \) with each unit of activity adding one unit of F.B.I. as an element in \( p_n' \).

As farming proceeds, the resources owned by farmers in a specific size-class might become limiting, given the value that the economy could realize from expanded farming operations in one size-class or other. There would be, therefore, advantages to including activities in \( q_n \) that represented the hiring-in of factor services. In addition to this, the inclusion of hire-in activities would permit a linkage between \textit{ex ante} factor service supply in the economy, (supply created through the potential for a size-class' selling factor services as income-earning activity) and \textit{ex ante} demand created if farming activity of one farm size-class or other was to expand. Such a linkage would essentially close the economy. Thus for each class, four additional activities are specified for inclusion in \( q_n \). The cost to the class of hiring in a unit of a specific factor service (a negative element in \( p_n'' \)) would be identical to the expected income per unit to be earned by a service seller in another class.

The activities involved in a group's deriving income from consumer durables, \( I_{(t-m)\eta} \), are not explicitly stated in the application. Rather, the contribution of consumer durables to income are subsumed in the direct earnings of labor and F.B.I.
The assumption implicit here is that the consumer durable adds to the capability of the labor resource to perform the tasks for which it is remunerated.

A transfer-payment-receiving activity is similarly excluded, on the assumption that the economy in a laissez-faire state assigns a zero-level target to a given individual's income. If policy were to be investigated in which a government sets income targets at non-zero levels, however, explicit provision would have to be made for the transfer activity to assume a non-zero value. But policy questions are not of concern at the moment.

A complete definition of $q_n$ and $p'_n$ is now possible for each group. The activities in $q_n$ include:

- renting out and renting in of land  
  (2 activities)

- leasing out of movable capital to each of the other groups, and the leasing in of capital  
  (5 " )

- hiring out of labor to each of the other groups and the hiring in of labor  
  (5 " )

- the hiring out of bullock power and to each of the other groups and the hiring in of bullock power  
  (5 " )

- farming as a single aggregate enterprise  
  (1 " )

Total (per farm-size class)  
(18 activities)

There would be a unique per-unit income receivable for each sale of factor service, a unique per-unit cost for each factor service purchased, and F.B.I. earned from the farming activity.
c. Resource constraints  Each group owns a resource stock which is classified into five generic types: land (measured in hectares), family labor (measured in days per year available), fixed capital (capital₁ in rupee terms, including buildings, non-marketable and non-salvageable implements and other fixed capital), movable capital (capital₂ including irrigation equipment and other items that can be leased out) and bullocks (measured in terms of days per year available). Hence, \( q^*_n \) has five elements, expressed as upper limits.

Hired labor inputs are not distinguished from family labor inputs on the assumption that both types perform the same tasks (excluding management, which is treated as a residual). Permanent servant labor is likewise not distinguished from family labor. The presumption is, however, that hired labor is used only in the farming activity so that the families in a group cannot realize earnings by releasing hired labor from their farm employment.

Two resources that have not been explicitly specified are purchased seed and purchased fertilizer. The actual specification of these inputs as resource constraints, rather than simply subsuming their use in the production function that links land, labor, capital, and bullocks to F.B.I. (which has been done) would imply that they were "owned resources" which generate factor service flows that could be sold as an alternative to use in the farming activity. This is not the case
however.¹

In addition to the real resource constraints just defined, there would be need for the definition of a constraint to depict the operation of a "market" for each of the factor services transferred between farm size-classes. Having defined a hire-in activity for capital, labor, and bullock days for each of the 5 groups into which the other four groups could offer factor services, there is need for five markets for each type of factor service. For the land transfer between groups, the existence of a single rental price meant that a common pool could be defined into which all five groups could offer their land services and out of which all could rent in land. One land market would be sufficient therefore. Each of the sixteen market constraints would be defined as equality constraints, with a "right-hand-side" of zero. This would have the effect of restraining the sale of any unit of factor service by one group unless there was a demand for it reflected in an increased level of a "hire-in" activity by some other group. The net amount in the market would thus always be zero.

¹The intention is not to deny that the availability of seed and fertilizer may be a constraining factor on the growth of farm output. The nature of the seed and fertilizer constraint as it now is in India and policy suggestions for its removal are discussed in S. C. Jain, Price Behavior and Resource Allocation in Indian Agriculture (Bombay: Allied Publishers Ltd., 1968), and Government of India, Expert Committee on Assessment and Evaluation. Modernizing....
d. Input-output coefficients The matrix of input output coefficients, B, will be a 41 x 90 matrix, excluding slack activities. The majority of the non-zero elements (which are few in comparison with the number of zero elements) are units, the exception being the entries translating the limited factor service flows into farming activities. As in the standard programming convention, a positive unity indicates factor service use and a negative unity indicates factor service augmentation. The general configuration of non-zero coefficients is given in Figure 3.1 for a given group. This configuration is quickly generalized for the other groups by rearrangement of the positive and negative entries in the labor, capital and bullock rows.

2. Data sources and manipulations

All data for the quantification of the model are taken from the Studies in the Economics of Farm Management, (The Studies), for Uttar Pradesh, 1968-69. The district included is Muzaffar-Nagar. The data are unpublished as yet, and were collected as the Government of India surveyed 150 farms on a cost-accounting basis. The data are given on a farm-by-farm basis so that they approximate a mini-census.

a. Coefficients in the objective function The prices paid for days of bullock and human labor, by a given farm-size class are the simple quotients of the total amount paid by
Figure 3.1: Configuration of Input-Output Coefficients for Size-Class 1

ACTIVITIES FOR SIZE-CLASS

- Rent out Land
- Hire out Lab
- Lease out Cap
- Hire out Cap
- Lease out Lab
- Hire out Built
- Hire inBuilt
- Rent in Land
- Hire in Cap
- Lease in Lab
- Hire with Own Factors

CONTRACT

NAME

Enter

Engage

Move

Use

Figure

Block

Land Market

Enter

Engage

Move

Use

Figure

Block

Build Market

Enter

Engage

Move

Use

Figure

Block

Cap Market

Enter

Engage

Move

Use

Figure

Block

Lab Market

Enter

Engage

Move

Use

Figure

Block

 own Factors
farms in the class and the total number of days employed by all the members of the class. The rates received or potentially received by members of one farm size-class for letting-out resources services for use by others, is that rate that the others have usually paid. Renting out land earns Rs. 600. per hectare, and renting in land costs the same amount. Capital prices paid for lease in and received for lease out are assumed to be the ratio of the average class capital costs (imputed) to average class value of capital. The assumption is that a farmer in a given group would be willing to pay as much (or slightly less) for leased in capital as paid for maintaining his own.

Farm Business Income (F.B.I.) is given by deducting the value of paid-out expenses in cash and kind from the total value of output (also cash and imputed value). With the production function of farming being expressed on a per-hectare basis in the example the average F.B.I. per hectare is estimated as a simple quotient of total F.B.I. and hectares for the farm size-class as a whole. F.B.I. contains the return from farming accruable to each of the resources specified (land, labor, capital, and bullocks) in addition to the management required to profitably use seed, fertilizer, organize the operation, etc. The per-hectare quantity used in the model is a hectare-weighted average for the size-class, and is given in Table 3.4.
Table 3.4. Production function by farm size-class, initial specification, Muzaffar-Nagar,\(^a\) 1968-69

<table>
<thead>
<tr>
<th>Size-class marks (Hectares)</th>
<th>Per-hectare inputs</th>
<th>F.B.I. per hect. (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Labor (Days)</td>
<td>Cap. 1 (Rs.)</td>
</tr>
<tr>
<td>Under 2.02</td>
<td>147.23</td>
<td>1264.91</td>
</tr>
<tr>
<td>2.02-4.03</td>
<td>128.57</td>
<td>1008.12</td>
</tr>
<tr>
<td>4.04-6.05</td>
<td>104.20</td>
<td>526.73</td>
</tr>
<tr>
<td>6.06-10.0</td>
<td>89.52</td>
<td>772.18</td>
</tr>
<tr>
<td>Over 10.0</td>
<td>89.01</td>
<td>807.46</td>
</tr>
</tbody>
</table>


b. Initial resource levels  The resource availability (that is, days of human and bullock labor, rupees of capital, and hectares of land) specified initially is exactly that employed in each farm size-class. The estimate of these magnitudes is the simple sum of the resource uses in each farm size-class reported in the Studies...1968-69 (see Table 4.4b).

c. Input-output coefficients  The Studies...1968-69 provide the basic data for estimating the input-output coefficients that convert resources into farming activities that generate units of F.B.I. (the "a" values in Figure 3.1). For each farm size-class the hectare-weighted average use of human
labor, bullock labor, capital\textsubscript{1} and capital\textsubscript{2} are estimated. A unit is specified for the use of land. The unique per-hectare production functions used for each farm-size class are given in Table 3.4.

The various coefficients in the production functions suggest an interesting contradiction to what has been traditional wisdom concerning the agriculture of India, namely that there is an inverse relationship between farm size and efficiency.\textsuperscript{1} Here, the labor, capital\textsubscript{1} and bullock requirements are lower for the over 10.0 hectare farms than in the under 2.02 hectare farms. The traditional view has not always been expressed so that it was clear whether the "efficiency" referred to was allocative or technical. Never-the-less, a recent study claimed that the relationship held when overall economic efficiency was the criteria (economic efficiency being the union of both technical and allocative efficiency).\textsuperscript{2} However, the data used to support these conclusions have been generally drawn from The Studies of the 1954-57 era, while the data represented here has come from a relatively modern time.

\textsuperscript{1}A summary of the controversy up to 1968 is found in Jagdish Bhagwati and Sukhamoy Chakravarty, "Contributions to Indian Economic Analysis," Amer. Econ. Review, LIX, Part 2, 2-73 (September, 1969).

Crown and Srivastava have shown that even with the model presented by Lau and Yotopolous, there is no reason to assume that the inverse relationship holds in India after the green revolution (in fact they suggest that there is good reason to suspect the traditional view as well). Crown and Nagadevara have shown that this would probably be true for rice as well as for wheat-growing regions of India. It is evident therefore, that while there is not clear evidence in the production functions used in this study that there is a direct relationship between efficiency and farm size, the data do not preclude such being true.

3. The initial solution

With the parameters of the model defined and estimated as indicated in the preceding sections, it is reasonable to expect

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2Lau and Yotopolous soften their earlier claim that the inverse relationship holds and state that farms are probably equally efficient in an allocative sense, but that smaller farms possibly show greater technical efficiency. L. J. Lau and P. A. Yotopolous, A Simultaneous Equation Approach to Relative Efficiency, Memorandum 104, (Stanford: Research Center In Economic Growth, Stanford University, August, 1970).

that the initial solution (the set of activities giving the maximum value to the objective) would be that all resources were used in farming and that the selection of farming activities followed were distributed as in Table 3.3. This means that one would expect 17 units of farming 1.24 hectares, 33 units of farming 3.06 hectares, and so on. Alternatively, it means that one would expect 21.09 units of farming 1 hectare under the production function for the under 2.02 size-class, 100.97 units of farming 1 hectare under the production function for the 2.02-4.03 size-class, etc. This would be the expected outcome if farmers had indeed already found the point at which their incomes were at a maximum given the alternatives of farming or not, and if the economy did impartially find the maximum value of the objective, without regard for whose income contributed to it.

The model does in fact yield such a situation (solution given in Table 4.4a. It contains only five activities; one farming activity for each size-class, at the levels indicated by the acreage levels in Table 3.3). The model itself is assumed to be predicting the "correct" outcomes for the input data given, therefore.

The task now is to re-quantify the model with parameters that depict the situation that results from behavior typical of farmers in the various size-classes as they respond to the ongoing technical change.
IV. AN EXAMPLE OF THE MODEL IN OPERATION:

OUTCOME UNDER TECHNICAL CHANGE

In the current example, measuring the impact of technical change on size-distribution of income (and so, the distribution of welfare) involves (a) estimating the parameters of the model after the technical change has just commenced, (b) allowing the differential behavior of individuals to alter the structure of the resource base and optional activities, and (c) determining a new optimal set of activities. The strategy assumes that the technical change represents a permanent change in the production possibilities and that the capital that embodies the new technology is divisible. This means that no group is automatically excluded from using the new technology, although economic constraints may vary the levels at which new technology is employed.

The third chapter contained the construction of the initial post-technical-change state of the economy. That analysis is now extended to consider the impacts of (i) the behavior of individuals with respect to re-investment using the income generated in the "initial solution" and (ii) the opening of new production possibilities and production functions (as generators of income) as re-investment occurs. The specific technical change analysed here, the green revolution in wheat, does not violate the assumptions behind the use of this model.
A. Allocation of Income

A set of decisions is made in households concerning the allocation of income among various uses. Equation 2.3 in Chapter II showed the individual allocating a portion of income to the acquisition of capital (in human, non-human, and consumer durable forms; essentially for the improvement of his and his family's financial and social position over time). The equation could be viewed in ex post time as the identity

\[ Y = Y_C + A \]

The magnitude of \( A \) was determined by the individual through a set of discussions incorporating his intertemporal consumption preferences, attitudes towards risk and uncertainty, and his perception of prices versus productivity (the elements in the vector \( \delta \) would be the reduced form elements of his decision-making system). Data should reveal the net result of this allocation. The magnitude of \( A \) is itself, the sum of allocations among many forms of asset \( (A = \sum_j A_{q^j}) \) so that it too could be disaggregated to show the ex post allocations among various forms, data permitting.

1. Allocation of income for family improvement

The Program Evaluation Organization (P.E.O.) reports estimates of the expenditure patterns of adopters of the high
yielding wheat varieties in various states in India. They report the total expenditures of surveyed farms by state, on productive farm assets, consumer durables (that is, personal capital accumulation) social functions, institutional investment, loan giving and loan repaying. They also report these expenditures as per-farm averages for farms in different farm-size classes, but for all India as a whole. An obvious data problem thus presents itself: namely, the derivation of behavioral indications for farmers in a district of a state, with size-class subdivision available only at a national level.

It is assumed that the state of Uttar Pradesh weights the national averages sufficiently, so that the all-India farm size-class percentages (estimated based on the data given by P.E.O.) applies to that state's totals. Further it is assumed that the district of Muzaffar-Nagar (the current study district) is sufficiently representative of the state of U.P. that the indicated expenditures by farm size classes for the state apply to the farms in the district. The calculations based on these assumptions, and the resulting division of Farm Business Income into expenditures for family subsistence and expenditures for family improvement (that is, investment in production assets, social functions, consumer durables, etc.), are given in Table 4.1.

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Table 4.1. Allocation of farm business income between family maintenance and improvement, by farm size-class, 1968-69, Muzaffar-Nagar and Uttar Pradesh

<table>
<thead>
<tr>
<th>Per farm allocation</th>
<th>Farm size-class (hectares)</th>
<th>Under 2.02</th>
<th>2.02</th>
<th>4.04</th>
<th>6.06</th>
<th>10.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm business income</td>
<td></td>
<td>2,399.41</td>
<td>7,600.12</td>
<td>11,313.53</td>
<td>17,373.22</td>
<td>32,178.35</td>
</tr>
<tr>
<td>Expenditure on family improvement</td>
<td></td>
<td>1,558.80</td>
<td>2,786.00</td>
<td>6,638.27</td>
<td>7,137.27</td>
<td>10,212.90</td>
</tr>
<tr>
<td>Expenditure on family maintenance</td>
<td></td>
<td>840.61</td>
<td>4,814.12</td>
<td>4,675.26</td>
<td>10,235.93</td>
<td>21,965.45</td>
</tr>
<tr>
<td>Revised expenditure on family improvement</td>
<td></td>
<td>900.00</td>
<td>1,600.00</td>
<td>6,313.00</td>
<td>7,373.00</td>
<td>12,178.00</td>
</tr>
</tbody>
</table>


b Defined as expenditures on productive assets, consumer durables, social functions, loan giving and repayment and others.

c Estimated by subtracting expenditures for family improvement from Farm Business Income.

d Assuming an expenditure for family maintenance of Rs. 1500 for the under 2.02 hectare farms, with smoothing between other classes.
The results indicate a direct relationship between the size of farm and the level of expenditures both to maintain the household and to acquire capital, make and repay loans, engage in social functions and so on (the family improvement expenditures). The data support a hypothesis that the larger a farm in hectares, the larger the fixed commitments for maintenance of family and permanent servants.

The estimated maintenance level in the under 2.02 hectare class is extremely low, indicating that the level of estimated expenditure on "family improvement" is probably too large. Writings of other authors\(^1\) indicate that the minimum caloric intake per person per day could be purchased in Uttar-Pradesh for Rs 146, per annum, (in 1961-62) and that prices rose 168.7% between then and 1967-68, (so that the minimum could be purchased in 1967-68 for Rs 248). Further, if the average family size in rural communities among the poorest 20% of the population was about 6.0, then at least Rs 1,500 would be required to maintain the family. Consultations and personal observation support this view. An expenditure on family improvement of about Rs 900 is used subsequently. Further, there has been an arbitrary "smoothing" of the relationship between the expenditure estimates in all classes. The estimates of expenditures for family improvement used in the

subsequent analysis are listed in Table 4.1 as well.

2. Allocation of family improvement expenditures for productive asset acquisition

The estimated expenditures for family improvement given in Table 4.1 are further subdivided to indicate the amounts spent for various types of productive assets; land, land improvement, irrigation equipment, buildings, machinery and implements, and livestock. Again, the P.E.O. reports expenditure totals by state, but the expenditures by farm size-class on an "all India" basis. The class-specific family improvement expenditures given in Table 4.1 can thus be allocated among the various productive asset classes by subdividing the totals in accordance with the national percentages. These expenditures are given in Table 4.2.

To convert the amounts spent on various productive assets into new resources conformable with the definitions of resources in the model's constraints, estimates of the prices of units of land, and bullocks, and the number of days of power that could be expected from a bullock are required.

The price of land per hectare payable by a farmer in a given size class is assumed to be the per hectare asset value of land currently held in that class. A uniform price would not necessarily exist since farmers operating larger units would be in a position to bid higher for better available land.
Table 4.2. Allocation of expenditure for family improvement among productive assets, by farm size-class, 1968-69, Muzaffar-Nagar and Uttar Pradesh

<table>
<thead>
<tr>
<th>Item</th>
<th>Farm size-class (hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Under</td>
</tr>
<tr>
<td></td>
<td>2.02</td>
</tr>
<tr>
<td>Expenditure for improvement per farm(^a) (Rs.)</td>
<td>900.</td>
</tr>
<tr>
<td>Class total(^b) (Rs.)</td>
<td>15,300.</td>
</tr>
<tr>
<td>Fraction for production assets(^c)</td>
<td>0.408</td>
</tr>
<tr>
<td>Expenditure for production assets (Rs.)</td>
<td>6,239.</td>
</tr>
<tr>
<td>Portion for land(^d)</td>
<td>0.107</td>
</tr>
<tr>
<td>Amount (Rs.)</td>
<td>675.94</td>
</tr>
<tr>
<td>Price per hectare (Rs.)</td>
<td>6,000.</td>
</tr>
<tr>
<td>Effective land added (hectare)</td>
<td>0.11</td>
</tr>
<tr>
<td>% increase(^f)</td>
<td>0.5</td>
</tr>
<tr>
<td>Portion for buildings&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.095</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Portion for machine and implements&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.012</td>
</tr>
<tr>
<td><strong>Total fixed capital (Rs.)</strong></td>
<td>674.03</td>
</tr>
<tr>
<td>% increase&lt;sup&gt;f&lt;/sup&gt;</td>
<td>2.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Portion for irrigation equipment&lt;sup&gt;d&lt;/sup&gt;</th>
<th>0.125</th>
<th>0.160</th>
<th>0.221</th>
<th>0.223</th>
<th>0.178</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Amount (Rs.)</strong></td>
<td>787.96</td>
<td>3,272.62</td>
<td>21,024.18</td>
<td>29,615.58</td>
<td>34,269.29</td>
</tr>
<tr>
<td>% increase&lt;sup&gt;f&lt;/sup&gt;</td>
<td>12.5</td>
<td>6.4</td>
<td>42.1</td>
<td>19.4</td>
<td>15.4</td>
</tr>
</tbody>
</table>

<sup>a</sup>From Table 4.1.

<sup>b</sup>Multipled per-farm expenditure by the number of farms in the class (17, 33, 32, 37, and 31 farms respectively).


<sup>d</sup>Fraction of total expenditure on productive assets spent on item, Government of India, Report on High Yielding Varieties...

<sup>e</sup>Assumed values, since the asset value was below that of next smallest farm-size class with which the families in this class would have to compete for renting in or buying land.

<sup>f</sup>New additions as percent of original constraint level.
<table>
<thead>
<tr>
<th>Item</th>
<th>Farm size-class (hectares)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Under 2.02</td>
<td>2.02</td>
<td>4.04</td>
<td>6.06</td>
<td>Over 10.0</td>
</tr>
<tr>
<td></td>
<td>2.02</td>
<td>-4.03</td>
<td>-6.05</td>
<td>-10.0</td>
<td></td>
</tr>
<tr>
<td>Portion for bullocks&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.662</td>
<td>0.509</td>
<td>0.280</td>
<td>0.275</td>
<td>0.193</td>
</tr>
<tr>
<td>Amount (Rs.)</td>
<td>4,188.53</td>
<td>10,451.89</td>
<td>26,662.96</td>
<td>35,855.81</td>
<td>27,057.75</td>
</tr>
<tr>
<td>Price per bullock&lt;sup&gt;g&lt;/sup&gt;</td>
<td>463.43</td>
<td>612.42</td>
<td>591.63</td>
<td>655.90</td>
<td>686.88</td>
</tr>
<tr>
<td>Pairs bought (no.)</td>
<td>3</td>
<td>4.89</td>
<td>13.43</td>
<td>16.89</td>
<td>15.16</td>
</tr>
<tr>
<td>Days worked per pair&lt;sup&gt;g&lt;/sup&gt;</td>
<td>40</td>
<td>63.0</td>
<td>73.6</td>
<td>78.5</td>
<td>102.3</td>
</tr>
<tr>
<td>Days added</td>
<td>120</td>
<td>308.2</td>
<td>989.0</td>
<td>1,326.2</td>
<td>1,551.0</td>
</tr>
<tr>
<td>% increase&lt;sup&gt;f&lt;/sup&gt;</td>
<td>17.1</td>
<td>10.3</td>
<td>26.6</td>
<td>20.3</td>
<td>18.3</td>
</tr>
</tbody>
</table>

<sup>g</sup>Government of India, Studies..., Uttar Pradesh, 1968-69, pp. 91-105.
The estimated asset value of land in each farm-size class is calculated as a simple average from data in The Studies, and listed in Table 4.2. Buying land, of course, is not the only means of effective acquisition; since there could be land reclamation activity, or land improvement that increases the effective hectarage relative to a previous time period. Land improvement expenditures are added to land acquisition expenditure for this reason.¹

The Studies contain data on the asset value of livestock on a farm-by-farm basis. It is assumed that all livestock have the capacity to be draught animals and that the price payable per head is the present asset value per head. The average number of head acquired, by class, is thus estimated (see Table 4.2). The Studies also give the data from which the average number of days worked per bullock-pair on farms of each size-class is estimated. The total number of days of bullock power available is given as the product of the estimated number of head acquired and the estimated work output per head (see Table 4.2).

Capital constraints (Capital 1 and Capital 2) were initially expressed in rupee terms, so that expenditure estimates are already conformable to original constraint definition. The

¹The growth in effective hectarage farmed is not large enough to place any farm in a farm-size class other than the one which it was initially assigned.
labor constraint is not changed by behavior in this example. In the period covered, even by the "long" run, it is presumed that neither population or the labor force has time to grow.\(^1\) However, the individual is permitted to transfer his labor to different employers in the model. The model thus shows laborers as earning a rent on an essentially fixed supply as productivity increases.

B. New Production Possibilities

Over time, and in conjunction with the process of acquiring new productive assets, it becomes possible for the farmer to change the production patterns that lead to his generating farm business income and family welfare. He has the option of altering the input mix for any given unit of land area, as he responds to changes in relative market prices, and changed relative physical productivities in the inputs. He has the option of changing the scale, or capacity of inputs by switching to more crop-specific and specialized equipment, land configurations, labor types and so on. He could also alter the mix of enterprises to align them with projected or

\(^1\)In the study, the "long" run refers to the time it takes for farmers to learn of and begin to apply the production techniques of individuals with different farm sizes. This time would be shorter than that usually associated with "the long run"; when say, fixed capital lost some of its fixity. In this model capital that is initially fixed is always fixed.
revealed changes in prices, or profitabilities. The limit to which he can exercise the options, however, is still constrained by the level of available resources after new resources are acquired, and the competing uses of class-specific factors.

In the short run, suppose that the individual identifies with farmers in his own size-class.\(^1\) Also, assume he prefers to try demonstrated methods rather than be experimental, to minimize uncertainty as to outcomes. Thus, in the short run, a farmer is viewed as considering the demonstrated production methods within his size-class, as possible candidates for introduction on his farm.

Data in the Studies is sufficient for the estimation of intra-size-class production functions representing the production demonstrated by sub groups in a size-class. The per hectare levels of labor, capital, leasable capital, and bullock power, along with the level of F.B.I. per hectare were estimated for 5 sub-classes within each size-class.\(^2\) These sub-classes subdivide the size-class into fifths, according to a ranking of the farm business income earned. Thus, for

\(^1\)The short run is the period in which the farmer is most aware of the possibilities already demonstrated by farmers of his own size, in the context of this model.

\(^2\)In the under 2.02 hectare class, only 3 sub-classes are defined.
farmers in each size-class, there would be an alternate production function yielding a high farm business income per hectare, one yielding a medium high income, and one yielding a medium, a second smallest and a small or low income. The resource requirements of these alternatives are given in Table 4.3. The model places no requirement that all of the resources be used in one-and-only-one production pattern, since the 5 variants and the class average variant would be considered as competitive but not mutually exclusive.

In time, however, farmers can be viewed as coming to recognize the possibilities for increasing F.B.I. per hectare by adopting the demonstrated production patterns of farmers in other size-classes. For example, a farmer of 10 hectares might anticipate earning more by considering his holdings as two 5-hectare holdings, and farming accordingly. However, a farmer of 5 hectares would be constrained by size of holding from aspiring to the per-hectare income available to a farmer of 10 hectares by considering himself as operating a 1/2-a-ten-hectare holding. In this time, arbitrarily called the "long run"¹, therefore, it is assumed possible for farmers to imitate the production patterns of farms in smaller size-groups, but

¹In reality this "long" run may cover a small amount of time, since it would be possible for a farmer to go through the entire stepped process of reinvestment and process-change simultaneously, and plan for this simultaneous change without separating his thought processes.
<table>
<thead>
<tr>
<th>Class and subclass designation</th>
<th>Per hectare input</th>
<th>F.B.I. (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Labor (days)</td>
<td>Capital $^c_1$ (Rs.)</td>
</tr>
<tr>
<td>Under 2.02</td>
<td>147.23</td>
<td>1264.91</td>
</tr>
<tr>
<td>Farm 1 Lo</td>
<td>156.00</td>
<td>1393.11</td>
</tr>
<tr>
<td>Farm 1 Md</td>
<td>153.08</td>
<td>1354.88</td>
</tr>
<tr>
<td>Farm 1 Hi</td>
<td>157.73</td>
<td>833.75</td>
</tr>
<tr>
<td>2.02-4.03</td>
<td>128.57</td>
<td>1008.12</td>
</tr>
<tr>
<td>Farm 2 Lo</td>
<td>128.80</td>
<td>1752.34</td>
</tr>
<tr>
<td>Farm 2 Sc</td>
<td>142.53</td>
<td>485.14</td>
</tr>
<tr>
<td>Farm 2 Md</td>
<td>129.11</td>
<td>799.87</td>
</tr>
<tr>
<td>Farm 2 Mh</td>
<td>133.91</td>
<td>971.55</td>
</tr>
<tr>
<td>Farm 2 Hi</td>
<td>134.41</td>
<td>1218.20</td>
</tr>
<tr>
<td>4.04-6.05</td>
<td>104.20</td>
<td>526.73</td>
</tr>
<tr>
<td>Farm 3 Lo</td>
<td>99.34</td>
<td>949.58</td>
</tr>
<tr>
<td>Farm 3 Sc</td>
<td>104.37</td>
<td>380.66</td>
</tr>
<tr>
<td>Farm 3 Md</td>
<td>102.09</td>
<td>319.96</td>
</tr>
<tr>
<td>Farm 3 Mh</td>
<td>107.43</td>
<td>315.64</td>
</tr>
<tr>
<td>Farm 3 Hi</td>
<td>115.05</td>
<td>635.37</td>
</tr>
<tr>
<td>6.06-10.0</td>
<td>89.52</td>
<td>772.18</td>
</tr>
<tr>
<td>Farm 4 Lo</td>
<td>90.30</td>
<td>790.61</td>
</tr>
<tr>
<td>Farm 4 Sc</td>
<td>97.30</td>
<td>607.54</td>
</tr>
<tr>
<td>Farm 4 Md</td>
<td>108.69</td>
<td>1154.79</td>
</tr>
<tr>
<td>Farm 4 Mh</td>
<td>80.76</td>
<td>516.50</td>
</tr>
<tr>
<td>Farm 4 Hi</td>
<td>78.24</td>
<td>505.41</td>
</tr>
<tr>
<td>Over 10.0</td>
<td>89.01</td>
<td>807.46</td>
</tr>
<tr>
<td>Farm 5 Lo</td>
<td>67.02</td>
<td>317.22</td>
</tr>
<tr>
<td>Farm 5 Sc</td>
<td>99.57</td>
<td>459.44</td>
</tr>
<tr>
<td>Farm 5 Md</td>
<td>76.87</td>
<td>1060.76</td>
</tr>
<tr>
<td>Farm 5 Mh</td>
<td>92.45</td>
<td>368.73</td>
</tr>
<tr>
<td>Farm 5 Hi</td>
<td>113.30</td>
<td>1897.59</td>
</tr>
</tbody>
</table>


$^b$Lo, Sc, Md, Mh, Hi, designate low, second lowest, medium, medium high and high F.B.I. per hectare respectively.

$^c$Capital$_1$ is fixed, capital$_2$ is variable.
not possible for them to imitate patterns of larger farms.

C. The Economy After Technical Change

The initial, short run and long run solutions for the groups in the economy are stated in Table 4.4a. These solutions should not be interpreted as representing a "before" and "after" situation with respect to the technical change, rather they should be viewed together as indicating a trend of change set in motion by the advent of the green revolution. Table 4.4b contains a statement of the levels of resource use and shadow prices.

1. The solution's acceptability

The initial solution was judged to be acceptable, because it precisely reflected the known situation in 1968-69 farm size and structure of activities. The short-run solution, appears acceptable, judged by equally subjective criteria. First, all land in the economy is employed, which is consistent with an a priori impression that the economy is land-scarce. Second, there is no evidence of "brokerage" in the system; that is farmers do not hire-in and hire-out the same resource and make a profit on the trade. Third, no size-class hires-in resources and allocates these to slack or non-use. There is slack in the system, however, indicating that either some of the decisions to acquire resources were not motivated by short-run profit
Table 4.4a. Initial, short run, and long run optimal activities and levels

<table>
<thead>
<tr>
<th>Class and activity</th>
<th>Initial activities and levels</th>
<th>Short run activities and levels</th>
<th>Long run activities and levels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Under 2.02</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROL1</td>
<td>--</td>
<td>21.1</td>
<td>21.1</td>
</tr>
<tr>
<td>HOL1T3</td>
<td>--</td>
<td>3105</td>
<td>--</td>
</tr>
<tr>
<td>HOL1T5</td>
<td>--</td>
<td>--</td>
<td>3105</td>
</tr>
<tr>
<td>LOC1T5</td>
<td>--</td>
<td>--</td>
<td>7088</td>
</tr>
<tr>
<td>HOB1T5</td>
<td>--</td>
<td>--</td>
<td>631</td>
</tr>
<tr>
<td>Farm 1</td>
<td></td>
<td>21.09</td>
<td></td>
</tr>
<tr>
<td><strong>2.02-4.03</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROL2</td>
<td>--</td>
<td>93.4</td>
<td>101.6</td>
</tr>
<tr>
<td>HOL2T3</td>
<td>--</td>
<td>392</td>
<td>--</td>
</tr>
<tr>
<td>HOL2T4</td>
<td>--</td>
<td>--</td>
<td>7534</td>
</tr>
<tr>
<td>HOL2T5</td>
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<td>--</td>
<td>5448</td>
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<td>LOC2T5</td>
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<td>54273</td>
</tr>
<tr>
<td>HOB2T5</td>
<td>--</td>
<td>1094</td>
<td>--</td>
</tr>
<tr>
<td>Farm 2</td>
<td></td>
<td>100.97</td>
<td>--</td>
</tr>
<tr>
<td>Farm 2 Hi</td>
<td></td>
<td>8.26</td>
<td>--</td>
</tr>
<tr>
<td><strong>4.04-6.05</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>RIL3</td>
<td>--</td>
<td>12.65</td>
<td>--</td>
</tr>
<tr>
<td>ROL3</td>
<td>--</td>
<td>--</td>
<td>160.00</td>
</tr>
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<td>--</td>
<td>16344</td>
</tr>
<tr>
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<td>--</td>
<td>3497</td>
<td>--</td>
</tr>
<tr>
<td>LOC3T5</td>
<td>--</td>
<td>14717</td>
<td>70234</td>
</tr>
<tr>
<td>HOB3T5</td>
<td>--</td>
<td>415</td>
<td>4675</td>
</tr>
<tr>
<td>Farm 3</td>
<td>158.14</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Farm 3 Hi</td>
<td>--</td>
<td>173.75</td>
<td>--</td>
</tr>
<tr>
<td>Farm 2 Hi in 3</td>
<td>--</td>
<td>--</td>
<td>1.11</td>
</tr>
<tr>
<td><strong>6.06-10.0</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HIL4</td>
<td>--</td>
<td>--</td>
<td>7534</td>
</tr>
<tr>
<td>HOL4</td>
<td>--</td>
<td>2894</td>
<td>--</td>
</tr>
<tr>
<td>LOC4T5</td>
<td>--</td>
<td>--</td>
<td>5927</td>
</tr>
<tr>
<td>Farm 4</td>
<td>282.24</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Farm 4 Hi</td>
<td>--</td>
<td>285.96</td>
<td>100.33</td>
</tr>
<tr>
<td>Farm 2 Hi in 4</td>
<td>--</td>
<td>--</td>
<td>185.63</td>
</tr>
<tr>
<td><strong>Over 10.0</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RIL5</td>
<td>--</td>
<td>101.81</td>
<td>282.72</td>
</tr>
<tr>
<td>HIL5</td>
<td>--</td>
<td>14373</td>
<td>24897</td>
</tr>
<tr>
<td>LIC5</td>
<td>--</td>
<td>14717</td>
<td>137522</td>
</tr>
<tr>
<td>HIB5</td>
<td>--</td>
<td>1508</td>
<td>5306</td>
</tr>
<tr>
<td>Farm 5</td>
<td>425.81</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Farm 5 Mh</td>
<td>--</td>
<td>383.58</td>
<td>--</td>
</tr>
<tr>
<td>Farm 5 Hi</td>
<td>--</td>
<td>148.42</td>
<td>--</td>
</tr>
<tr>
<td>Farm 2 Hi in 5</td>
<td>--</td>
<td>--</td>
<td>73.80</td>
</tr>
<tr>
<td>Farm 3 Hi in 5</td>
<td>--</td>
<td>--</td>
<td>78.22</td>
</tr>
<tr>
<td>Farm 4 Hi in 5</td>
<td>--</td>
<td>--</td>
<td>560.88</td>
</tr>
</tbody>
</table>
Table 4.4b. Resource use levels and shadow prices in initial, short run and long run optimal solutions

<table>
<thead>
<tr>
<th>Class and resource&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Initial use&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Short run use</th>
<th>Short run s.p&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Long run use</th>
<th>Long run s.p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under 2.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>21.1</td>
<td>21.1</td>
<td>14,55.85</td>
<td>21.1</td>
<td>2,553.84</td>
</tr>
<tr>
<td>Labor</td>
<td>3,104.0</td>
<td>3,105.0</td>
<td>12.59</td>
<td>3,105.0</td>
<td>3.367</td>
</tr>
<tr>
<td>Capital&lt;sup&gt;1&lt;/sup&gt;</td>
<td>26,677.0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Capital&lt;sup&gt;2&lt;/sup&gt;</td>
<td>6,300.0</td>
<td>--</td>
<td>--</td>
<td>7,088.0</td>
<td>0.229</td>
</tr>
<tr>
<td>Bullocks&lt;sup&gt;$&lt;/sup&gt;</td>
<td>702.0</td>
<td>--</td>
<td>--</td>
<td>630.8</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.02-4.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>101.0</td>
<td>101.6</td>
<td>1,435.85</td>
<td>101.6</td>
<td>2,553.84</td>
</tr>
<tr>
<td>Labor</td>
<td>12,982.0</td>
<td>12,982.0</td>
<td>12.59</td>
<td>12,982.0</td>
<td>3.367</td>
</tr>
<tr>
<td>Capital&lt;sup&gt;1&lt;/sup&gt;</td>
<td>101,790.0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Capital&lt;sup&gt;2&lt;/sup&gt;</td>
<td>51,000.0</td>
<td>--</td>
<td>--</td>
<td>54,272.6</td>
<td>0.229</td>
</tr>
<tr>
<td>Bullocks&lt;sup&gt;$&lt;/sup&gt;</td>
<td>2,993.0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.04-6.05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>158.1</td>
<td>161.1</td>
<td>1,456.85</td>
<td>161.1</td>
<td>2,553.84</td>
</tr>
<tr>
<td>Labor</td>
<td>16,493.0</td>
<td>16,493.0</td>
<td>12.59</td>
<td>16,493.0</td>
<td>3.267</td>
</tr>
<tr>
<td>Capital&lt;sup&gt;1&lt;/sup&gt;</td>
<td>83,297.0</td>
<td>110,397.0</td>
<td>0.086</td>
<td>1,349.9</td>
<td>--</td>
</tr>
<tr>
<td>Capital&lt;sup&gt;2&lt;/sup&gt;</td>
<td>49,900.0</td>
<td>29,986.0</td>
<td>--</td>
<td>70,724.0</td>
<td>0.229</td>
</tr>
<tr>
<td>Bullocks&lt;sup&gt;$&lt;/sup&gt;</td>
<td>3,719.0</td>
<td>4,718.0</td>
<td>--</td>
<td>4,708.0</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>6.06-10.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>282.2</td>
<td>286.0</td>
<td>1,972.52</td>
<td>286.0</td>
<td>2,554.25</td>
</tr>
<tr>
<td>Labor</td>
<td>25,267.0</td>
<td>25,267.0</td>
<td>12.59</td>
<td>25,267.0</td>
<td>3.370</td>
</tr>
<tr>
<td>Capital1</td>
<td>217,939.0</td>
<td>144,527.0</td>
<td>--</td>
<td>276,845.0</td>
<td>(++)d</td>
</tr>
<tr>
<td>Capital2</td>
<td>152,900.0</td>
<td>173,892.3</td>
<td>--</td>
<td>182,515</td>
<td>0.229</td>
</tr>
<tr>
<td>Bullocks</td>
<td>6,517.0</td>
<td>5,708.0</td>
<td>--</td>
<td>7,588.3</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Over 10.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>425.8</td>
<td>430.2</td>
<td>1,456.85</td>
<td>430.2</td>
<td>2,554.84</td>
</tr>
<tr>
<td>Labor</td>
<td>37,904.0</td>
<td>37,904.0</td>
<td>12.59</td>
<td>37,904.0</td>
<td>3.370</td>
</tr>
<tr>
<td>Capital1</td>
<td>343,822.0</td>
<td>423,072.1</td>
<td>0.034</td>
<td>423,072.1</td>
<td>(++)</td>
</tr>
<tr>
<td>Capital2</td>
<td>222,100.0</td>
<td>256,369.0</td>
<td>(++)</td>
<td>256,369.2</td>
<td>0.230</td>
</tr>
<tr>
<td>Bullocks</td>
<td>8,492.0</td>
<td>10,043.0</td>
<td>(++)</td>
<td>10,043.0</td>
<td>--</td>
</tr>
</tbody>
</table>

\( ^a \) Resource units are hectares (land), rupees (capital) and days (labor and bullocks).

\( ^b \) Use only, since shadow prices are assumed to be market prices in this case.

\( ^c \) Zero shadow price indicates quantities of factor not used.

\( ^d \) (++) indicates shadow price of less than Rs. 0.01.
maximizing anticipations, or that acquisition errors were made relative to the profit maximizing criteria.

The long run solution (that found when farmers are permitted to apply the demonstrated production functions of farmers in smaller size-classes, but not those in larger) meets similar criteria of acceptability. In addition, when the long-run production possibilities are allowed, even fewer resources were committed to non-use compared to the short-run solution. Notably, the category of capital (capital_, mainly irrigation equipment) subject to lease-out arrangements, is fully employed in the long run. Bullocks are traded, but there is slack bullock power in the economy so that a marginal value of bullocks is zero. Any income earned by hiring out bullocks would thus be the result of pure bargaining, or hiring jointly with labor.

2. Class-specific impacts

A summary of the net receipts accruing to families in farming, families who used to farm, and traditionally hired labor is given in Table 4.5. The following discusses these magnitudes:

a. Families initially in the under 2.02 hectare class

As new investment permits new production possibilities in the short-run, the marginal value of labor increases (as indicated
Table 4.5. Summary of size-class distribution of income in initial, short run and long run optimal solutions

<table>
<thead>
<tr>
<th>Income source and class</th>
<th>Initial (rupees)</th>
<th>Short run (rupees)</th>
<th>Long run (rupees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 2.02</td>
<td>40,787</td>
<td>--</td>
<td>-- 6</td>
</tr>
<tr>
<td>2.02-4.03</td>
<td>250,808</td>
<td>26,115</td>
<td>--</td>
</tr>
<tr>
<td>4.04-6.05</td>
<td>362,025</td>
<td>420,125</td>
<td>3,504</td>
</tr>
<tr>
<td>farming</td>
<td>642,807</td>
<td>787,662</td>
<td>875,505</td>
</tr>
<tr>
<td>Over 10.0</td>
<td>999,528</td>
<td>1,029,276</td>
<td>1,526,449</td>
</tr>
<tr>
<td></td>
<td>(2,295,955)</td>
<td>(2,263,078)</td>
<td>(2,405,457)</td>
</tr>
<tr>
<td>To</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under 2.02</td>
<td>--</td>
<td>65,818</td>
<td>64,986</td>
</tr>
<tr>
<td>2.02-4.03</td>
<td>--</td>
<td>260,485</td>
<td>309,000</td>
</tr>
<tr>
<td>farmers</td>
<td>--</td>
<td>--</td>
<td>462,683</td>
</tr>
<tr>
<td>4.04-6.05</td>
<td>--</td>
<td>462,683</td>
<td>--</td>
</tr>
<tr>
<td>as rents</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>and wages</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Over 10.0</td>
<td>--</td>
<td>--</td>
<td>(326,303)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(836,699)</td>
</tr>
<tr>
<td>Total wages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under 2.02 (317)</td>
<td>827</td>
<td>3,991</td>
<td>1,067</td>
</tr>
<tr>
<td>2.02-4.03 (1978)</td>
<td>5,459</td>
<td>24,903</td>
<td>6,660</td>
</tr>
<tr>
<td>4.04-6.05 (1060)</td>
<td>12,954</td>
<td>63,705</td>
<td>17,037</td>
</tr>
<tr>
<td>hired men</td>
<td>6.06-10.0 (9116)</td>
<td>24,796</td>
<td>114,770</td>
</tr>
<tr>
<td>in class</td>
<td>Over 10.0 (19090)</td>
<td>48,107</td>
<td>240,343</td>
</tr>
<tr>
<td></td>
<td>(92,143)</td>
<td>(447,713)</td>
<td>(119,734)</td>
</tr>
<tr>
<td>Value of economy</td>
<td>2,388,098</td>
<td>3,037,094</td>
<td>3,360,860</td>
</tr>
</tbody>
</table>

* a Days of hired labor initially employed.

b Underestimated by amounts paid out to bullocks, leased in capital, taxes and land, traditionally hired in even in the initial stages. This amount is fairly small, however.
by the divergence of the shadow price of labor\(^1\) upwards from the market price in the initial period. Similar tendency occurs for land value.\(^2\) By hiring out all of the 2788 family labor-days (including the permanent servant labor) and renting out the land newly acquired and previously used in independent farming, the families in the class could anticipate short-run earning of Rs. 65,819, or about Rs. 3,872 per family (see Table 4.6). This represents a 61 percent increase over the income per family earned from farming alone. Indeed, even if the resources of the under 2.02 hectare size-class were employed in the "high F.B.I. per hectare" variant, the class would only realize an income of about Rs. 45,000 before land became limiting. The members of the small farm size-class, therefore, are considerably better off relative to their own former positions by hiring out labor and renting out land.

In the long run, these families lose income because the marginal value of labor declines\(^3\) (but still exceeds the market prices paid in the initial situation), but gain as the marginal

\(^1\)Shadow price of labor in shorter-run is Rs. 12.59 as opposed to a market price of Rs. 2.52-2.76 depending on the purchaser (Table 4.4b).

\(^2\)Shadow price of land, Rs. 1455.82, versus land rental of Rs. 600.00 per hectare.

\(^3\)Longer run shadow price of Rs. 3.367 per labor day.
<table>
<thead>
<tr>
<th>Class and number</th>
<th>Initial</th>
<th>Short run</th>
<th>Long run</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>rupees-</td>
<td>rupees-</td>
<td>rupees-</td>
</tr>
<tr>
<td>Landless (40)</td>
<td>2,303.57</td>
<td>11,130.00</td>
<td>2,995.84</td>
</tr>
<tr>
<td></td>
<td>(+4.845)(^a)</td>
<td>(+1.298)</td>
<td></td>
</tr>
<tr>
<td>Under 2.02 (17)</td>
<td>2,399.</td>
<td>3,872.</td>
<td>3,823.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(+1.614)</td>
<td>(+1.593)</td>
</tr>
<tr>
<td>2.02-4.03 (33)</td>
<td>7,600.</td>
<td>8,685</td>
<td>9,364</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(+1.143)</td>
<td>(+1.232)</td>
</tr>
<tr>
<td>4.04-6.05 (32)</td>
<td>11,313.</td>
<td>13,126</td>
<td>14,568</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(+1.160)</td>
<td>(+1.288)</td>
</tr>
<tr>
<td>6.06-10.0 (37)</td>
<td>17,373.</td>
<td>21,288.</td>
<td>23,662.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(+1.225)</td>
<td>(+1.362)</td>
</tr>
<tr>
<td>Over 10.0 (31)</td>
<td>32,243.</td>
<td>33,203.</td>
<td>49,240.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(+1.030)</td>
<td>(+1.527)</td>
</tr>
</tbody>
</table>

\(^a\)Parenthetical figures give the ratio of the income estimate relative to the initial income estimate.
value of land increases past the value of the shorter-run magnitude. In the longer run, as leasable capital becomes scarce in the economy, these families also gain as they lease out capital. Overall, the families in the class realize about Rs. 64,986, or Rs. 2,823 per family (a 59 percent increase over the initial per-family income).

Actually receiving this income however, depends on the family's ability to bargain for wage, interest, and land rent rates that reflect the actual marginal value of the input in use; that is, the estimate is based on the assumption that the labor, land and capital markets are perfectly competitive (free of market imperfections). If there are market imperfections or factor-service monopsony, so all benefits of technical change were allowed to accrue to the users of hired-in resources (assuming that the rates in the initial period were paid) the families in the small farm-size class could expect only about Rs. 20,600 or about Rs. 1,212 per family. This is considerably below the income of mere subsistence of Rs. 1,500 per family considered earlier. With longer term production possibilities open the families might expect about Rs. 1,800 per

---

1 Longer run shadow price of Rs. 2553.84 per hectare.

2 Longer run shadow price of Rs. 0.229 per rupee-value leased out.

3 This would be the value if labor earned Rs. 2.56 per day and land earns Rs. 600.00 per hectare.
family.\(^1\)

But with the existence of these market imperfections, the small farm-size families would not abandon independent farming, even if all hired-in labor were bid away. Using family labor alone, families could expect to earn at least Rs. 36,850 or about Rs. 2,170 per family from farming their own land.\(^2\) Therefore the farmers in this small-farm size-class would only release the land and labor (and capital in the longer run) necessary for the expansion of production in larger units if they were paid at least half of the marginal value of the resources in use as wage and rental rates.\(^3\)

\[\text{b. Families initially in the 2.02-4.03 hectare class}\]

The small level of farming carried out by families in this class in the short run indicates that they all but abandon independent farming. After releasing the 1978 labor days that were formerly hired-in, and employing about 1110 family days in reduced farming activity, labor wages and land rent earns about Rs. 260,485 for the class. With the farming activity

\[\text{\footnotesize{(1) Assuming again that labor earns Rs. 2.52 per day, land earns Rs. 600.00 per hectare and capital earns Rs. 0.12 per rupee-value leased out.\(^2\)}}\]

\[\text{\footnotesize{(2) This assumes that 2788 family days used in the average farming activity permits 19 units of farming to occur, which earns Rs. 1,946 of F.B.I. per unit.\(^3\)}}\]

\[\text{\footnotesize{(3) In the short run, if labor and land were paid only half of their marginal value, the small-farm families would earn about Rs. 2,540 each, which would constitute a net gain over the initial state.\(^3\)}}\]
included, the families enjoy income of about Rs. 8,684.83 per family, representing an increase of about 14 percent compared with the initial situation. In the longer run, assuming that the wage, rental and lease-out rates are equivalent to the marginal value of the resources, the families in the class earn Rs. 309,000 or about Rs. 9,363 per family (a 23 percent increase).

As in the case of the small-farm families, the income estimates are made assuming that resource owners receive factor service rates equivalent to the factors' marginal values. In the case of this farm-size class, resources in the short run would have to be paid at least 3/4 of the marginal value in order for families to be as well off hiring-out as they were when farming, using their own resources in independent farming.¹

c. Families initially in the 4.04-6.05 hectare class

In the short run, farm families in this class tend to adopt the production mix and scale demonstrated by the farmers earning the highest F.B.I. per hectare in their class. This is not

¹At initial market prices, families as a whole earn Rs. 127,386. The difference between the market and shadow-price values of resources is Rs. 159,213. If families in the class receive Rs. 120,000 in addition to the Rs. 127,386, or three-quarters of the marginal value of land and labor, they receive Rs. 247,386. This compares with Rs. 250,808 earned from farming in the initial stages. Actually, if farmers in this class moved to a higher income variant of the farming activity, they would need to be paid even more than the three-quarters of the marginal value of abandon farming, since their opportunity cost would have risen.
simply due to the fact that the return per hectare is higher, but also is dependent on the lower resource uses per unit in the production function. The class realized income of Rs. 516,693. This is an overestimate, however; since the measure of F.B.I. per hectare reported in Table 4.3 is calculated assuming that hired-in resources are paid the initial market rates. But if labor and land are assumed to receive rates identical to their marginal values, the true value of F.B.I. per hectare would be lower. The difference is the new marginal value less the initial market price, times the number of units of hired-in resource. The adjusted short run overall F.B.I. is Rs. 420,025 or about Rs. 13,126 per family (an increase of 16 percent over the initial per-family income).

In the long run, however, farmers in this class find it profitable to cease independent farming, in spite of their adopting the production patterns, scale, and mix of inputs typically employed by farmers in the next smallest size-class (the high income variant of the 2.02-4.03 hectare class). They can earn an overall income of Rs. 466,186 or about Rs. 14,568 per family (an even larger increase relative to the initial situation) by renting all but a small amount of land, hiring out family labor, and leasing out unused capital, at rates identical to the marginal values of the resources.
d. Families initially in the 6.06-10.0 hectare class

With the acquisition of resources, families in this class tend to adopt the production patterns, output mix, and input mix demonstrated by the earners of high F.B.I. per hectare within their own class, in the short run. Again, for this class, the per-hectare F.B.I. indicated in Table 4.3 overestimates the actual F.B.I. attainable if producers are forced to pay the marginal value per unit employed. The F.B.I. earned by the class as a whole when adjusted for the difference between the marginal value of factors and the initially paid rates, is Rs. 787,662 or about Rs. 21,288 per family. This is a 23 percent increase over the initial per-family F.B.I.

In the solution, the farm families appear to be adopting more capital intensive practices since they are shown to be releasing (hiring out) labor. The 2894 days released is assumed not to be family labor since there is still hired labor employed in the short run solution, and in this economy it is assumed that a farm would release hired labor before family labor.

In the long run, another production pattern would be optimal for families in the 6.06-10.0 hectare class. They would combine the former high-income variant demonstrated by

\[1\text{There were 9116 hired-in days employed in the initial solution, to supplement the 16,151 family and permanent servant days. With 2894 days released, there would still be 6223 hired days employed.}\]
farmers of their own class, and the high income variant of the former 2.02-4.03 hectare class. This combination is apparently labor intensive relative to the short run situation, since the solution shows families in this class hiring in labor while leasing out capital. In this case, as in the short run situation, they are required to pay the difference between the initial market price and the marginal value of labor assuming that the wage rate approaches the marginal value. After adjustment, the class realizes Rs. 875.504 and families realize on the average Rs. 23,662 (which is a 36 percent increase over the initial per-family F.B.I.).

e. Families initially in the over 10.0 hectare class

Farm families in this class tend to adopt the production techniques of the farmers in the class formerly earning high and medium-high levels of F.B.I. as they make new investments. This is not an obvious or simplistic result since the production functions of these two variants given in Table 4.3 show that these two variants tend to be more costly in terms of labor, bullock power, and capital than the average variant used in the initial solution. The short run solution shows the families in the class renting in land, leasing in capital and hiring in labor. When the F.B.I. earned is adjusted for the assumption that the rates paid out are identical to the
marginal values of resources,\(^1\) and the labor already employed in
the class income is Rs. 1,029,278. Each family realizes an
increase of about 3 percent relative to their initial positions.

In the long run, however, families in this class tend to
adopt the technologies yielding the highest income per hectare
in the 2.02-4.03 hectare class, the 4.04-6.05 hectare class,
and the 6.06-10.0 hectare class. When adjusted for differences
between the initial market rates paid out and the marginal
value of resources, F.B.I. per family increases by 53 percent.\(^2\)

f. Initially landless families Although not explicitly
included, the model encompasses income earning activities for
landless rural families. In Uttar Pradesh, typically, 20 per­
cent of all families in rural areas are landless.\(^3\) In the
current example, with 150 farming (therefore landed) families
as representative of the state economy, 40 landless families
would be implicitly present in the model. Each family would
contribute on average 890 days of labor to agriculture. This
represents full-time employment for a family of 6 (the average

\(^1\)The adjustment includes the payment of the difference
between the short run shadow price of land, Rs. 1455.82 and the
initial rental price of Rs. 600.00 per hectare.

\(^2\)The adjustment includes the payment of the difference
between the long run shadow price of land, Rs. 2553.84, and the
initial rental price of Rs. 600.00 per hectare.

\(^3\)Government of India, Cabinet Secretariat, National Sample
rural family size) for 5 months of the year. This is a reason-
able situation considering that there are generally 2 seasons
of 2-1/2 months each in which intensive hand planting, weeding,
and harvesting occurs.

Under these conditions, and with wage rates as in the
initial period, an average family would earn Rs. 2,304 per
year. If labor earned its full marginal value, a landless
family would earn up to Rs. 2,996 in the long run situation.
This would be a 30 percent increase.

D. Implications of the Solutions

1. Relative size-distribution of income under technological
change

The size-distribution of income among groups is depicted
in two ways, in Table 4.7; the first showing relative per-
family incomes with respect to that of the average family in
the under 2.02 hectare class, the second, with respect to the
per-family income of the 4.04-6.05 hectare group.

The ratios, presented in Table 4.7 indicate that the
disparity between large and small farm family incomes (when
families are identified as in the initial solution) is not
growing. But there is less relevance in using terms like
"farm family" in these short run and long run situations.
Farms in the under 2.02 hectare class cease their independent
operations in the model, hence they cannot continue wearing the
Table 4.7. Incomes per family relative to the under 2.02 hectare\(^a\) class, and the 4.04-6.05 hectare class in initial, short run and long run optimal solutions

<table>
<thead>
<tr>
<th>Size-class (hectares)</th>
<th>Initial</th>
<th>Short run</th>
<th>Long run</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landless</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>w.r.t. under 2.02</td>
<td>0.96</td>
<td>(-^c)</td>
<td>0.78</td>
</tr>
<tr>
<td>w.r.t. 4.04-6.05</td>
<td>0.20</td>
<td>(-^c)</td>
<td>0.21</td>
</tr>
<tr>
<td>Under 2.02</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>w.r.t. under 2.02</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>w.r.t. 4.04-6.05</td>
<td>0.21</td>
<td>0.30</td>
<td>0.26</td>
</tr>
<tr>
<td>2.02-4.03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>w.r.t. under 2.02</td>
<td>3.17</td>
<td>2.24</td>
<td>2.45</td>
</tr>
<tr>
<td>w.r.t. 4.04-6.05</td>
<td>0.67</td>
<td>0.66</td>
<td>0.64</td>
</tr>
<tr>
<td>4.04-6.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>w.r.t. under 2.02</td>
<td>4.72</td>
<td>3.39</td>
<td>3.81</td>
</tr>
<tr>
<td>w.r.t. 4.04-6.05</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>6.05-10.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>w.r.t. under 2.02</td>
<td>7.24</td>
<td>5.50</td>
<td>6.19</td>
</tr>
<tr>
<td>w.r.t. 4.04-6.05</td>
<td>1.54</td>
<td>1.62</td>
<td>1.62</td>
</tr>
<tr>
<td>Over 10.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>w.r.t. under 2.02</td>
<td>13.44</td>
<td>8.58</td>
<td>12.88</td>
</tr>
<tr>
<td>w.r.t. 4.04-6.05</td>
<td>2.85</td>
<td>2.53</td>
<td>3.38</td>
</tr>
</tbody>
</table>

\(^a\)Calculated from Table 4.6.

\(^b\)w.r.t. = with respect to.

\(^c\)Ratio ignored since in short run, marginal value of labor is excessively high, which makes ratio unreliable.
label of "small farm". Indeed the farmers of the 4.04-6.05 hectare class apparently become the "small farmers" in the long run, and the disparity between the family incomes of this group and those in the over 10.0 hectare class grows (see the ratios relative to the family income of the 4.04-6.05 hectare class).

But with a landless class included, and the discussion framed in terms of "rural" families (not farm families), the impact of the technological change becomes clear (see Table 4.7). While all families gain, the families that continue farming on a large scale (those in the 6.06-10.0 hectare and the over 10.0 hectare classes) improve relatively. The families that become fully dependent on the resource markets for income (the landless, under 2.02 hectares, and the 2.02-4.03 hectare farm families) tend to lose relatively, even though the families that originally farmed holdings of under 2.02 hectares make some relative gain. Among families remaining as independent cultivators, the spread in relative income grows.

Farmers initially within the over 10.0 hectare class gain relative to both the farms in the 6.06-10.0 hectare and those in the 4.04-6.05 hectare classes. Further, farms in the 6.06-10.0 hectare class gain relative to those in the 4.04-6.05 hectare class.¹

2. Relative factor shares under technological change

The analysis permits the quantification of changes in the functional income distribution following the technical change. A complete analysis of all factors is not possible in each iteration, since the shadow prices of resources going unused is zero. However, an analysis of the land and labor share is possible throughout, and a longer run indication of capital's share is suggested. The comparison of shares, and the ratios of income of labor to land and to capital is given in Table 4.8.

In the initial situation, the returns to land, labor and capital are the prices received per unit hired, rented out or leased out. The assumption is that the cost-accounting procedure used in collecting the data for the Studies sets prices equal to the marginal products. The value of labor in the initial situation is the sum of the values of hired-in labor (given in Table 4.5) and family labor as given in the Studies. The return to capital is the product of the quantity of capital employed and the interest rate that the farmer is willing to pay for the next unit leased in summed over classes. Land earns a uniform Rs. 600.00 per hectare. In the short and long runs, the return to resources is the product of the shadow price (the marginal value of the resource) and the quantity employed.
Table 4.8. Factor shares changes, initial, short run, and long run optimal solutions

<table>
<thead>
<tr>
<th>Item</th>
<th>Initial(^a)</th>
<th>Short run(^b)</th>
<th>Long run(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Values</td>
<td>(rupees)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- land</td>
<td>592,950.</td>
<td>1,455,809.</td>
<td>2,553,763.</td>
</tr>
<tr>
<td>- labor</td>
<td>227,168.</td>
<td>1,205,505.</td>
<td>322,394.</td>
</tr>
<tr>
<td>- capital</td>
<td>56,673.</td>
<td>--</td>
<td>130,664.</td>
</tr>
<tr>
<td>- economy</td>
<td>2,388,098.</td>
<td>3,037,094</td>
<td>3,360,860.</td>
</tr>
<tr>
<td>Ratio of values</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- lab/land</td>
<td>0.38</td>
<td>0.83</td>
<td>0.13</td>
</tr>
<tr>
<td>- lab/cap</td>
<td>4.01</td>
<td>--</td>
<td>2.47</td>
</tr>
<tr>
<td>Shares w.r.t. economy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- land</td>
<td>0.25</td>
<td>0.48</td>
<td>0.76</td>
</tr>
<tr>
<td>- labor</td>
<td>0.10</td>
<td>0.40</td>
<td>0.10</td>
</tr>
<tr>
<td>- capital</td>
<td>0.02</td>
<td>--</td>
<td>0.04</td>
</tr>
</tbody>
</table>

\(^a\) Land: no. of hectares farmed times Rs. 600 (imputed rent)
Labor: value paid or imputed for hired and family labor reported in the Studies
Capital: imputed rates of interest to capital times the amount of variable capital (capital\(_2\)) employed
Economy: from Table 4.5, including net returns to farming plus wages paid to hired in labor.

\(^b\) Each input item value is the product of the amount employed times the marginal value product. Economy value is taken from Table 4.5. The difference between the value of the economy and the sum of labor and level shares is the share attributed to fixed inputs.

\(^c\) Each input item value is the product of the amount used and the marginal values product. Economy value is from Table 4.5. The difference between the economy value and the sum of shares is the share attributed to other fixed factors.
The short run distribution is somewhat distorted by the fact that fixed capital has no revealed marginal value. But the long run distribution shows that land and capital gain, relatively, while labor simply retains its relative position. This indicates that the technological change tends to be land and capital augmenting.
V. SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

A. Model Characteristics

The typical means of studying the effects of technical change on the distribution of income has been through the study of changing relative factor shares. This type of analysis begins with the definition (or at least the assumption) of a fully aggregated macro production function in which variables such as "labor" or "capital" are arguments. From knowledge of factor share movements, however, only weak inference can be drawn to the likely impacts of technical changes on the relative sizes of individuals' incomes.

The model developed in the second chapter was designed to explicitly show the impacts of technical change directly as leading to changed relative incomes of individuals (or near-homogeneous groups of them). The model allowed for the measurements of the impacts without prior regard for the source of the families income flow or what factor-service earned the income. Throughout, a maintained assumption was that attaining a maximum level of income under the constraints imposed by market prices, demands and factor availabilities would be necessary before an individual could begin to maximize his welfare.
The model employed an optimization procedure, and so served to indicate what could be attained under the constraints impose, not what would occur within some confidence limit. In addition, the prediction was internally consistent.

As a bonus, the impacts of technical change could be observed as they influence relative factor shares as well as individuals' incomes.

B. Empirical Findings

When quantified with data for 1968-69, depicting a district agricultural economy in India (the Muzaffar-Nagar district of Uttar Pradesh), the model yields several results of interest, bearing on several issues of current interest with regard to India's green revolution in wheat production.

1. Optimal activities

In the models' solutions, there is a tendency for farming activities to concentrate in the hands of the farm families cultivating the largest holdings. Families initially farming smaller holdings tend to "rent" out their land and to hire out their labor services to the operators of the larger farms (see Table 4.4a). In the model, the concept of "renting" was maintained, although this could mean selling and taking a form of mortgage payment over time for the title.

Of real significance, moreover, is the fact that this tendency, predicted by this model as being an optimal situation,
has actually been observed in an ongoing occurrence. Frankel cites cases in the Punjab in which small landowners overcome the capital constraints to their adopting the H.Y.V.'s as they "'rent' out small holdings of 2 to 4 acres to large farmers, who then supply the actual owners with the modern inputs for cultivation and take 50 percent of the crop as their share."¹

The indication in the model is that small farmers have been able to realize larger incomes by, essentially, abandoning independent cultivation (but not necessarily resource ownership) (see Table 4.6). Large farms have also benefited from the opportunity to expand the sphere of management, and earn added returns for their own fixed resources in the process. It is also significant that as large land owners expand, they move to adopt the production practices previously demonstrated on smaller farms.

2. Income distribution

As would be expected, it is possible under reorganization, for the value of the economy to increase after technical change. With the base parameters selected, indications are that there can be a 40 percent output growth relative to the initial value, under full adjustment (the long run) and one of 27 percent

with partial adjustment with a moderate infusion of new productive assets (land, power sources, fixed capital, and movable or leasable capital, but the same labor force) (Table 4.5).

The results suggest that a set of circumstances exist in which all participants in the agricultural economy can gain relative to their own initial positions, including landless laborers, when the economy attains the new optimum (Table 4.6). Granted, there is an implicit assumption that factors earn their marginal value products as returns per unit of resource, which implies an absence of market imperfection. Nevertheless, this result is significant in that it shows that a general improvement in individual welfare would be possible from policy to removing market imperfections. Elaborate programs of wealth and asset redistribution would not be required to attain a Pareto efficient outcome from the technical change (although they might be required to attain other goals related to equity and relative income distribution).

This application of the model has not assumed, directly, which factors would be favoured in technical change. Yet the results of the analysis show that the green revolution could be characterized as being land and capital (movable capital) augmenting if the input parameters reflect reality (Table 4.8). Labor retains its share of the economy's value and gains in absolute amount. Fixed factors, including fixed capital and management lose relatively.
The central concern in this study, however, has been with the redistributing effects of the technical change with respect to family incomes. The application indicates that income earned by farm-operating families (those who remain in farming in the long run situation) becomes generally less equitably distributed (Table 4.7); as the ratio of per-family income of large farms in relation to that of medium sized farms grows from 2.85 to 3.38. Further the ratio of per-family income of the largest to next-largest farms grows from 1.85 to 2.08.\(^1\)

The more significant finding, moreover, is that there would be a general divergence in the relative incomes of rural families (including the initially landless and those who cease independent farming operations in the long run). The exception to this divergence is the relative rise in the incomes of the initially small farms (the under 2.02 hectare class) (Table 4.7). This divergence occurs in spite of a general rise in the income level of all families relative to their respective former positions.

\(^1\)This divergence of relative farm incomes is in agreement with the qualitatively predicted divergence given in Carl H. Gotsch, "Technical Change and the Distribution of Income in Rural Areas," Amer. Journ. of Agric. Econ., LIV, p. 339 (May, 1972); under the assumption that the green revolution is a simple, divisable, and labor-using technical change, that there is a general lack of community organization for equitable distributions, and the assumption that Indian social organization is largely hierarchical.
C. Conclusions and Implications

1. With respect to the model

The model appears to be capable of indicating the "correct" outcome of a technical change as viewed for the standpoint of income distribution among families or individuals. When applied to the agricultural economy, the optimization indicate a tendency in the size-distribution that is consistent with the qualitative predictions in abstract of Gotsch,¹ and the semi-empirical predictions of Srivastava, Crown and Heady² (who used a set of equations based on farm production functions to analyse the distribution problem).

By correctly predicting the impacts of technical change on size-distribution of income, in the absence of policy changes, moreover, the model might reasonably be expected to yield accurate predictions of the outcomes of policy change as well. The improvement in the basis for social policy formulation represented by this model can be indicated in a brief demonstration. Recall the demonstration in Chapter I that factor share information would only weakly infer the likely changes in the

¹Gotsch, "Technical change and..."

size-distribution of income. The model in application showed labor to be a relatively losing factor; from which might be inferred that laboring families are relative losers also. In the model, the landless families, offering only one factor service for sale, were indeed, relative losers, so that the inference from factor share movements is strong (both directionally and in extent).

In a contrasting case, however, consider the families initially farming holdings of under 2.02 hectares (who were the most labor intensive cultivators per hectare) in relation to farms of over 10.0 hectares (the least labor intensive per hectare). While land is seen to "gain" three-fold with respect to labor, (see Table 4.8) families on average in the large-farm class "lose" relative to the labor intensive farms, by 4 percent (see Table 4.7; the ratio of 12.88 to 13.44 is about 0.96). Relative factor share movements indicated neither the direction nor the extent of the change in relative incomes. The relative gains of small-farm family participation in land and capital markets, essentially compensated them for relative losses incurred by participating in labor markets.

The model presented in this study, therefore, makes a contribution by providing a systematic framework for the determination of the "net" family income impacts of diverse shifts in factor shares.
2. With respect to optimal organization of agriculture

The tendency in the optimal situations resulting after the technical change has had an opportunity to influence the economy is for factor services to be employed in the initially larger farms, in conjunction with the management and fixed capital of those farms. These flows of factor services realign without necessary changes in ownership patterns of assets.

a. Factor intensity Of significance, moreover, is the indicated structure of production that appears optimal; that is, the selection of production functions made as the optimal set and the combination of them at different levels on the farms continuing to operate (see Table 4.3 for specification of the alternatives, and Table 4.4 for the functions selected and their levels).

In the long run solution, farms in the 6.06-10.0 hectare and over 10.0 hectare classes recombine production functions previously employed by farms of smaller acreage that have ceased independent activity. In so doing, the configuration of production tends to become more labor intensive in both classes.1

1In the initial situation, farms in the 6.06-10.0 hectare class employ a production function which has a capital-labor ratio of 14.7 and a labor-land ratio of 90 days per hectare. These ratios become 13.8 and 115 days per hectare in the longer run solution. For the farms in the over 10.0 hectare class, the capital-labor ratio goes from 14.9 to 13.8 and the labor-land ratio falls from 89 to 88 days per hectare.
b. Relative efficiency  

The tendency for large farms to imitate the technical production functions of previously smaller farms is significant for the question of relative economic efficiency in Indian agriculture. This question, in turn is significant, in that knowledge of relative efficiency would guide government policy as it seeks to stimulate growth with efficiency.

When there were ample real alternatives in the model for forming the optimal set, having a selection taken from the production functions of the initially smaller farms means that small farms were the most efficient technically, in terms of using least amounts of resources per unit of output. The question of the relative allocative efficiency of small versus large farm families is not at issue in this model, however. Indeed, the model has assumed that there was no difference in the allocative efficiency of farm families. In optimal situations large farm-size families would tend to employ the technical relationships formerly employed by the smaller farms. Whether or not small farms used to be relatively more efficient, therefore, (even in the technical sense) becomes irrelevant for discussions of current or future policy.

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1 This conclusion is supported by L. J. Lau and P. A. Yotopoulos, A Simultaneous Equation Approach to Relative Economic Efficiency, Memorandum 104, Research Center in Economic Growth (Stanford: Stanford University, 1970).
c. Cooperatives  The interpretation of the long run behavior of formerly small farms has been that they rent and hire out land and labor to larger farms. But their activity at optimum can also be interpreted as being their abandonment of independent management, such as would occur in the formation of cooperatives. As a practical matter, the encouragement of the formation of cooperatives is a part of current Indian agrarian policy\(^1\) and the success of the policy has been subject of controversy.\(^2\)

Jain has indicated that there might be gains from cooperatives particularly for farmers of small fragments:

"where individual farming has lost its meaning because of almost inconceivably small-scale operations".\(^3\)

The problem would be one of discovering and emphasizing the rewards of cooperation as an incentive to overcoming the barrier of social status attached to independence.

---

\(^1\)For a statement of some of the issues involved, see R. S. Shiwalker, "Agricultural Organization," in Changing Indian Agriculture, edited in S. C. Jain, 128-68 (Bombay: Vora and Co., 1966). Shiwalker discusses the Panchayati Raj or government instigated cooperatives, the independent cooperatives and the credit cooperatives, their formation and problems.


The solution in the present model indicates that there would be considerable economic reward accruing to the small farmers from cooperation. The estimates of income per family given in Table 4.6 were calculated on the basis that there would be the same number of families after the technical change as before it. Suppose, however, as an example, that instead of the 31 families in the over 10.0 hectare class that the Rs. 1,526,449 total income for the class was to be divided by 40 "families" (in this case let the 9 new "families" be cooperatives). In this case, the per-family income would be Rs. 38,161, and the average farm size would be about 14 hectares (compared to Rs. 49,240 per family and 18 hectares with 31 farms). There would still be an improved family income possible for the farm initially in the over 10.0 hectare class, but the increase would be 18 percent with respect to the its initial per-family income, rather than the 53 percent growth accruing in the absence of cooperatives.

If the initial holding size in the 2.02-4.03 hectare class is 3.06 hectares and the average holding for the under 2.02 hectare farms is 1.24 hectares (Table 3.1) only 4 of the 2.02-4.03 hectare farms, or 11 of the under 2.02 hectare farms would have to cooperate to farm a 14-hectare cooperative.¹

¹In the study, there would be enough farms to form 9 extra families out of the 17 farms initially under 2.02 hectares and the 33 farms initially between 2.02 and 4.04 hectares.
The long run per-family income of Rs. 38,161 would be sufficient to give each of the 4 cooperating farm families an income of Rs. 9,540 (or a 26 percent increase compared with the initial farm family income in the 2.02-4.04 hectare class) (see Table 4.6). Each of the 11 cooperating families would receive Rs. 3,470, which is less than the amount attainable without cooperation (Rs. 3,823; see Table 4.6), but which is still an increase of 45 percent with respect to the initial family income of one in the under 2.02 hectare class.¹

Cooperation would lead to improved income distribution in addition to income growth as in the example. The ratio of income per family between the average over 10 hectare and the under 2.02 hectare farm would be 11.00 under cooperation, compared to the 12.88 in the long run without cooperation (Table 4.7). The ratio of income per family between an average over 10 hectare farm and one in the 2.02-4.04 hectare class would be 4.00 with cooperation compared with 5.25 in the long run without cooperation (calculated from Table 4.6).

For these reasons, cooperation might, indeed, be a viable alternate to policies of land redistribution, taxation with transfers, subsidization for inputs and price supports. To

¹The assumption of 10 farms cooperating rather than 11 would make the income from cooperation competitive with that attainable without cooperation.
some degree this has no doubt been recognized in India, where recent policy has been to increase the amounts of and decrease the terms and length of debt period for loans made through credit cooperatives.¹

3. With respect to rural employment

The tendency for the optimal set and levels of production activities to be relatively labor intensive, given the production pattern of the initial stage, raises the question of the capacity of the green revolution to be employment creating. Johnston and Cownie suggest that the potential might be large, in light of experience in Japan and Taiwan, and events in Pakistan's adaptation of the new seeds.² Frankel observed a growing demand for year-round labor in the Punjab, and a particularly high demand at harvest time (demand exceeding supply, even including in-migration).³

With the present model and application, the question can be restated to ask the level of labor force employable at different marginal value products. As an experiment, the number

¹These activities of the Reserve Bank of India (India's central bank and major institution for monetary policy) are reviewed in Government of India, Expert Committee on Assessment..., Modernizing...


³Frankel, India's Green Revolution, p. 35.
of days of labor available for hire (that is, the effective labor force) was raised parametrically in 1 percent increments through 10 iterations. This eventual 10 percent increase in labor availability would be consistent with a 25-30 percent growth in population, given current participation rates.\(^1\)

As would be expected as a limiting resource increases in an optimization problem, the value of the program grew and the marginal value of the resource in use fell. However, the 10 percent growth in labor supply was sufficient only to reduce the marginal value by 1/3 of a percent (from 3.367 to 3.357), while the value of the objective rose by about 1 percent.

The application here suggests that the reorganized agriculture and would be able to offer employment opportunities well in excess of likely increases in labor supply.

4. With respect to policy for equitable redistribution

The agreement between the conclusion of the study and others, that the distribution of income among individuals following the green revolution will likely become more inequitable, raises questions as to what policy instruments might be helpful in regaining equity. Two commonly posed answers are

found in the proposals for land redistribution, and taxation of the relative "gainers" with the transfer payments to the relative loosers (that is reliance on resource and fiscal policy).

a. Land redistribution to landless individuals

The results of the application show, that in the long run, creating a farm of average size in the under 2.02 hectare class (that is, making one 1.24 hectare farm) penalizes the value of the economy in excess of Rs. 780\(^1\) if the average experienced production function for that class (as given in Table 4.3) is put into effect on the new farm. If the production function appropriate to the highest income farms in the class in the initial state was put into effect, the income foregone by the economy would be greater than zero, but by an unknown amount.

But, by establishing such small farms for landless families, the policy maker would be, in effect, granting them an annual income of Rs. 2400 if the average production function were used, or an income of Rs. 3154.56 if the best-earning production function was enforced. This would improve their incomes, even relative to their income under the long run wage

\(^1\)The estimate of Rs. 780 is taken from the standard output of the program of optimization, being the per-unit income sacrifice to the economy of forcing a unit of the activity involved into the basis. The estimate would underestimate the cost of establishing the farm by the amount required to buy the land, the equipment, and so on to allow the operation to function.
rates (as in Table 4.6). Land redistribution appears, therefore, to have an equity benefit for these families.

But the equity goal cannot generally be served through this instrument. If a family who formerly farmed an average under 2.02 hectare holding independently were forced to continue farming (rather than renting out, hiring out labor, or forming a cooperative) they would be required to forgo the extra Rs. 669 earned by following another income earning strategy (the difference between the Rs. 3,823 that could be realized by the cessation of independent operations and the Rs. 3,154 accruing to a farm under the high income variant of farming).

b. Taxation and transfers A brief exploration of the possibility of taxing agricultural production with a tax per unit of land farmed is conducted in the context of the present study. Tax-paying was introduced as an activity in the analysis, linked to the farming activity so that both activities enter the basis together if either one does.

Using the average taxes per hectare paid in the size-classes as reported in the data collected in the Studies, the farming activities as reported in Table 4.4a are sufficient to generate a tax pool of Rs. 10,723.\(^1\) If redistributed equally

\(^1\)This is the sum of the following products: 1.11 x Rs. 13.32; 285.96 x Rs. 11.67; and 712.90 x Rs. 10.36. The latter numbers of each product are the tax rates. Notice, that tax rates are inversely related to the farm size, that is the tax system is regressive.
among the landless rural families, each family could increase its income by about 9 percent.

The long run solution to the optimization is fairly sensitive to changes in the tax rates however. The "range" around the given tax rate within which the tax could be varied without altering the basis or the value of the program is about 0.60 of a rupee. Therefore, an initial indication is that the existing method of taxation would not be useful for the collection of greater volume of resources needed for more extensive transfer schemes.

D. Suggestions For Quantitative Policy Analyses

The implications of the application seem to suggest that the model could yield quantitative answers to a variety of policy problems. Three possible extensions are mentioned here.

In the area of land policy: the model could be further employed even with the application as given, to explore the possible variants of land reform that might increase equity in rural income distribution more fully. Under a broader definition, a full resource policy, both with and without respect to cooperatives could be included. Possibly some combination of landless family participation with small-scale landed (or even moderately sized farm family) families could alleviate the uncertainty of the landless family with respect to income and welfare, and the uncertainty and constraint on the landed
family of adequate labor input simultaneously.

With this application, the trade-offs between the goals of growth in output and income and equity in the distribution of this income using land as a policy instrument could be fully quantified.

Considering tax policy: the model could be expanded to include the specification of various tax mechanisms other than the land tax currently in operation. Moreover, even within the confines of land tax; the redistribution impacts of government's striving for progressive (or at least not regressive) rate structures could be determined. With this, the relative gains and losses resulting from the tax policy could be simultaneously brought into the analysis.

Lastly, with regard to the employment potential of agriculture following the green revolution; other significant variables could be added to the analysis, within the context of the current application to account for the impacts of changing family size under growing income, migration propensities under wage-rate differentiation, the substitution of hired for family labor, and the extent of substitutability of machine for labor. (Considering the tendency for the economy to select the labor intensive production functions even when labor became a relatively more scarce input.) There would be distributional impacts of each of these elements that would be observable in the model at the family level.
VI. BIBLIOGRAPHY


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