MULTIOBJECTIVE PROGRAMMING OF INCOME AND EMPLOYMENT GENERATION IN SMALL SCALE AGRICULTURE: A CASE STUDY FROM KENYA

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Introduction

The major objective of this paper is to investigate the feasibility of generating substantially higher (20 percent or more) income and employment in Kenyan small scale agriculture under various policy options, using data from a selected area. Specific objectives are to: assess the impact of a declining land-labour ratio upon farm enterprise combination; measure and contrast the income and employment generating capacity of two agricultural development strategies--one which pursues the income maximizing objective, the other the employment maximizing objective; determine an optimal tradeoff between the income maximizing and employment maximizing objectives; and draw some policy implications from the major results.

Hypotheses

This paper tests three hypotheses, that there is capacity in Kenyan small scale agriculture to generate substantial (20 percent or more) increases in both income and employment; that the income and employment generating capacity of agriculture declines as the land-labour ratio decreases; and that there is an income-employment tradeoff in agricultural production. The first hypothesis will be tested by measuring the change in income and employment levels between existing farming systems (EFS) and optimal farming systems (OFS) under various policy scenarios. The second hypothesis will be tested by changes in income and employment levels as the land-labour ratio decreases. The test of the third hypothesis will be provided by a comparison of income and employment levels obtained by the income maximizing and employment maximizing models.

Policy Options

Income and employment impacts of six agricultural policy options are analyzed. First, it is assumed that farmers in the study area allocate their resources inefficiently. The aim is to determine changes in income and employment levels that ensue from an optimal allocation of farm resources.

Second, due to their risk aversion behaviour, small scale farmers undertake certain enterprises strictly to meet subsistence food requirements of their households. These enterprises would be precluded from production by income maximizing criteria. Accordingly, a policy scenario involving elimination of subsistence food production constraints is analyzed.

Third, a 20-percent increase in the profitability of farm enterprises is assumed, to come from increases in output prices, productivity, or both.

Fourth, many small scale farmers supplement their farm incomes with off-farm employment. Off-farm employment is provided by self employment in nonfarm activities and wage employment. Accordingly, a policy option assuming a 13-percent increase in off-farm employment opportunities is examined. The small increase reflects the difficulty of creating off-farm jobs.

Fifth, although land scarcity is acute in Kenyan small scale agriculture, valuable land remains unused on some farms. This is because some farmers lack sufficient resources, including time, while others make minimal effort to produce beyond immediate household subsistence requirements. On the other hand, many small scale farmers have resource capacity, time, and commercial desire to utilize more land than they command. Consequently, a policy of

promoting a land rental market between land surplus and land deficit farmers is analyzed. It is assumed that land deficit farmers could afford to rent land up to a fourth of their own farm size.

Sixth, the war on low rural incomes, underemployment, and unemployment requires an assault on several fronts. A composite policy scenario involving a simultaneous implementation of the above five policy options is therefore tested. However, instead of a complete elimination of on-farm subsistence food production, a more realistic 25-percent reduction is envisaged.

Methodology

Production data for the 1978-1979 crop year were obtained from a random sample of 38 farms in Mbiuni location of Machakos district in Kenya. Using a ratio of farm size in hectares to the number of household adult equivalent workers available for farm work (the Land-Adult Equivalent Ratio or LAER), the farm sample was divided into three farm groups, the low (0.80 ha), medium (1.31 ha), and high (2.35 ha) LAER farms. For each LAER group, a respresentative farm was developed by averaging land, labour, and capital resources over the entire group.

The purpose of the LAER was to focus the analysis on the effect of a declining land base per farm worker as farm population increases, while the purpose of grouping farms was to facilitate the representative farm analyses approach. Aggregation bias was minimized by the selection of relatively homogeneous farms; i.e., farms from the same agroecological zone and area.

Initially, income and employment levels of the EFS were computed from the survey data. Three linear programming (LP) models were then constructed for each representative farm. The first model assumed the orthodox income maximizing objective. The second model represented the employment maximizing objective. The third model maximized both income and employment simultaneously, using the multiobjective linear programming (MOLP) approach.

In the MOLP model, both the income maximizing and the employment maximizing objectives were expressed in a common monetary numeraire and aggregated into a single composite effective function as suggested by Russell (p. 65), and applied by Mukhebi (p. 179). The model was formulated as:

(1) maximize $Z(x) = \sum_{j=1}^{n} C_j X_j$

(2) subject to $\sum_{j=1}^{n} a_{ij} X_j < b_i$, $i=1, \ldots, m.$

(3) $\sum_{j=1}^{n} c_{js} X_j > b_s$

(4) $\sum_{j=1}^{n} c_{jt} X_j > b_t$

(5) $X_j > 0$, $j=1, \ldots, n.$

where $Z(x)$ = income-employment composite value,

X_j = level of the j^{th} activity,

a_{ij} = quantity of the i^{th} constraint per unit of the j^{th} activity,

b_i = level of the i^{th} constraint,

b_s = total household gross margin,

b_t = total man days of household employment,

c_{js} = gross margin per unit of the j^{th} activity,

c_{jt} = man days of employment per unit of the j^{th} activity,

and $C_j = c_{js} + kc_{jt}$,

where k = the average gross basic minimum consolidated wage per man day of labour in agriculture, as legislated by the government. It is a measure of the social value of a man day of employment by the rural population.

Equation (1) expresses the MOLP objective function. The larger the Cj, the more the j^{th} activity contributes to increasing income and employment simultaneously. Expressions (2) and (5) form the usual LP constraint set; (3) and (4) represent the income and employment maximizing objective functions respectively, formulated as additional constraints.

The MOLP model provides the best compromise solution, one in which both income and employment are maximized simultaneously, when b_s and b_t in expressions (3) and (4) are set equal to zero. At the best compromise solution, the marginal rate of trade-off between income and employment is equal to their inverse value ratio.

The objective function for each model was maximized subject to land, labour, capital, and subsistence food production constraints. Production and selling, labour hiring and selling, and capital borrowing activities were included in each model. The results of each model were weighted by the number of farms in each LAER group and aggregated over the sample.

Empirical Results

Existing Farming Systems

Under the EFS, food crops substituted for cash crops as the LAER declined. The average income per household person was Kenya shillings (Ksh) 700 (US $95, 1978). This was only 37 percent of the then per capita national income of Ksh 1,875 (US $255, 1978). The average income decreased as the LAER fell. On average for the entire sample, 53 percent of the labour supply was employed. As the LAER declined, the rate of employment decreased, increasing under-employment; and the rate of off-farm employment and off-farm income increased. Generally, all farms utilized resources efficiently from an economic standpoint. In particular, low LAER farms were relatively more efficient than high LAER farms. The results under the EFS verify the second hypothesis, that the income and employment generating capacity of agriculture declines as the land-labour ratio decreases.

Income Maximizing Strategy

The aggregate farm sample income and employment levels of the six policy options are presented in table 1. The results show that each policy option led to an increase in both income and employment beyond the levels observed under the EFS. However, income increased substantially in only four of the six options. On the other hand, employment rose substantially on only two options. The pursuit of all options simultaneously in a composite option provided the best results. The increase in income or employment in the composite option was much greater than that in any single option. This implies strong positive income or employment interactions among the various policy options.

Table 1. Farm Sample Aggregates of Income and Employment Generated Under the Income Maximizing Strategy for Various Policy Options, Mbiuni Location, Machakos District, Kenya, 1978/1979

Policy Option	Income		Employment	
	Amount	Percentage Change	Level	Percentage Change
	Ksh	%	MD	%
Existing farming systems	231,415	---	25,639	---
Efficient resource allocation under existing farming systems	239,930	+4	28,418	+11
Elimination of subsistence constraints	295,463	+28	29,730	+16
Higher producer prices and productivity	280,106	+21	28,497	+11
Higher off-farm employment	245,922	+6	29,617	+16
Establishment of a land rental market	292,944	+ 27	32,766	+28
Pursuance of a composite policy option	356,808	+54	33,668	+31

Employment Maximizing Strategy

The aggregated farm sample income and employment levels of the six policy options for the employment strategy are reported in table 2. The results indicate that each policy option generated a substantial increase in employment, especially the composite option. On the other hand, all the options except the composite option led to a decrease in income below the EFS level.

The 65 percent increase in employment by the composite option is greater than that of any individual option. This again illustrates the existence of positive interactions among the various policy options. This interaction is emphasized even more by the result that while each individual options led to a decrease in income, the composite option generated an 11-percent increase in income.

Table 2. Farm Sample Aggregates of Income and Employment Under the Employment Maximizing Strategy for Various Policy Options, Mbiuni Location, Machakos District, Kenya, 1978/1979

Policy Option	Income		Employment	
	Amount	Percentage Change	Level	Percentage Change
	Ksh	%	MD	%
Existing farming systems	231,415	---	25,639	---
Efficient resource allocation under existing farming systems	196,234	-15	35,005	+37
Elimination of subsistence constraints	193,297	-16	40,242	+57
Higher producer prices and productivity	223,111	-4	35,005	+37
Higher off-farm employment	190,807	-18	35,920	+40
Establishment of a land rental market	205,900	-11	41,256	+61
Pursuance of a composite policy option	256,750	+11	42,284	+65

Income Versus Employment Maximizing Strategies

For all six policy options, an overall average of the whole sample, the income maximizing model generated 36 percent more income but 20 percent less employment than the employment maximizing model. Conversely, on average, the employment model generated 26 percent more employment but 27 percent less income than the income model. The average income employment tradeoff was 2.07 man days of employment given up for each pound (Ksh 20) of income gained by the income strategy. Alternatively, the average tradeoff was Ksh 9.68 of income foregone for every man day of employment gained by the employment strategy.

These results verify the hypothesis that there is an income-employment tradeoff in agricultural production. The income maximizing objective sacrifices some employment in order to generate a higher level of income. Alternatively, an employment maximizing objective would forfeit some income to generate a higher level of employment.

Multiobjective Programming Approach

The best compromise solutions are presented in table 3. Each policy option increased employment substantially. However, all options except the composite option did not generate substantial increases in income. The MOLP composite option yielded the best results for the whole analysis. It generated very substantial increases in both income and employment of 45 to 60 percent respectively.

Table 3. Farm Sample Aggregates of Income and Employment Generated by the Multiobjective Linear Programming Model, Mbiuni Location, Machakos District, Kenya, 1978/1979

Policy Option	Income		Employment	
	Amount	Percentage Change	Level	Percentage Change
	Ksh	%	MD	%
Existing farming systems	231,415	---	25,639	---
Efficient resource allocation under existing farming systems	224,958	-3	34,531	+35
Elimination of subsistence constraints	256,461	+11	39,777	+55
Higher producer prices and productivity	265,621	+15	34,478	+34
Higher off-farm employment	232,100	0	35,427	+38
Establishment of a land rental market	272,844	+18	40,140	+57
Pursuance of a composite policy option	335,713	+45	41,118	+60

The best compromise solution income and employment levels for each policy option fell between those of corresponding uniobjective LP solutions reported in tables 1 and 2. This underlines the "compromising" feature of MOLP. The MOLP model, an average of all options, generated 23 percent more employment but only 7 percent less income than the income maximizing model. On the other hand, the MOLP model generated 26 percent more income with merely 2 percent less employment than the employment maximizing model.

The results in tables 1, 2 and 3 provide a test of the first hypothesis. They show that, under EFS, there is no capacity in small scale agriculture to generate substantially higher incomes and employment, even with the most efficient use of farm resources. However, introduction of changes into the EFS by pursuing a variety of policies concurrently could generate very substantial increases in both income and employment under the income maximizing or multiobjective programming approaches.

Conclusions and Policy Implications

Two overall conclusions can be drawn from the findings of this paper. First, the farm population becomes poorer as the land base per worker declines, due to a rising farm population. Generating higher farm incomes and employment becomes desirable for alleviating rural poverty. But in order to increase farm incomes and employment substantially, a variety of agricultural policies should be pursued concurrently to introduce changes into the existing farming systems. These policies should place more emphasis on food rather than cash crop production, and on labour-using and land-saving technologies rather than capital intensive ones.

Second, there is a tradeoff between income and employment in agricultural production. In order to maximize both income and employment, a multiobjective rather than a uniobjective programming approach should be followed. A multiobjective programming model approach would strike an optimal balance between the two objectives, taking into account the relative value of each objective to society.

Note

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References

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