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## **Production Efficiency in Peasant Agriculture: An Application of LISREL Model**

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## **Abstract**

The study examined a simplified conceptual model which incorporates variables that influence the processes and consequences of household decision-making in the Ada and Selale districts of the Ethiopian highlands. Linear structural relations (LISREL) analysis was performed on three conceptual models.

The results of LISREL analysis indicate that the magnitude of contribution of factors to production efficiency in descending order as: skill variables (e.g., experience, secular education and production knowledge), consequences of access to resources or institutions (e.g., wealth), technologies adopted, physical factors (e.g., land and labour) and extension education. The impact of inputs on production efficiency was greater among farmers who have adopted one or two technologies (Ada) and two or more technologies (Selale). Successful adoption can be attained if, given appropriate socioeconomic environment, skills of producers are matched to the requirements of technologies, and when the choice of technologies are compatible with the goals of households, experience, region and enterprise specific comparative advantages.

## **Production Efficiency in Peasant Agriculture: An Application of LISREL Model**

### **Introduction**

African, Asian and Latin American countries have been striving to produce adequate food for the poor. Several strategies, spanning from agri-led development, export-led growth to induced innovation have been implemented since the 1950's. Recently, "sustainable development", was adopted by policy makers as a feasible paradigm. Whether this paradigm is attainable is to be seen. In the mean time, agriculture had to develop to produce adequate food and generate income that would be channeled to other sectors of the economy.<sup>1</sup>

Agricultural development in major LDCs is constrained by scarcity of resources. Introduction of "appropriate" agricultural technologies that would not alter skills and management styles of peasants, and keep income differentials among farmers to the minimum is viewed as viable strategy. Examples of such kind of technologies include cross-bred cows that are intended to increase the productivity of local livestock breed.

The objectives of increasing food production, in light of limited financial and physical resources, can be attained by focusing on regions that can produce greater output with little investment. Furthermore, intervention strategies should identify geographic regions where the majority of the poor live.

Several studies have argued that if Ethiopia is to use its agricultural potential for development, the focal geographic or altitude zones should be the highlands (Getahun, 1978,

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<sup>1</sup> This statement should not be interpreted to imply unbalanced growth as a feasible strategy. Rather, it is intended to emphasize the urgency of the food production problem in LDCs.

1980; Sisay, 1980; Belay, 1977). The highlands offer diverse production techniques and opportunities for development (Getahun, 1978; Sisay, 1980). Possible methods of increasing food production include increases in area cultivated, productivity of land and other resources. The first possibility is difficult to achieve in the highlands because of high density of livestock and human population, and landscape that requires huge investment to be harnessed. Thus, if development is to benefit the majority of the Ethiopian poor, emphasis should be given to increasing the productivity of land and other resources while conserving those which are over-utilized.

Three crop and one livestock production technologies were introduced in two regions of the Central highlands of Ethiopia. The present study examines the feasibility of these intervention strategies by focusing on selected factors that impinge on the processes of decision-making and their consequences or outcomes.

## **The Problem**

Households make decisions to achieve various goals including production, consumption, and reproduction, among others.<sup>2</sup> Various micro and macro variables influence household decision-making and the consequences thereof. Similar set of micro and macro variables influence the design of development policies. Examination of the processes and consequences of household decision-making that include all macro and micro variables is a complex task.

A simple, yet realistic, framework for the conceptual definition of the problem investigated in this study is given in Figure 1 (see also Kebede, 1993). The conceptual

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<sup>2</sup> Caution should be exercised against taking a dogmatic definition of goals because, for some, goals can represent means or strategies, and for others they can be ends or aims.

framework is broadly divided into two parts. The first part deals with variables shaping the processes that lead to actual decision-making. The second part examines the quantitative outcome of decisions. Previous studies of decision-making at the household level have concentrated either on the first (e.g., Webb, 1988), or the second part (e.g., Ellis, 1988). The factors involved in the linkages between the two parts have not been examined in detail.

The conceptual model indicates that there are three types of variables. The first set includes exogenous variables such as crop and grazing area, education, experience, labour, oxen, feed, number of cows, seed and wealth. The second set includes endogenous variables such as the number of technologies adopted and production knowledge.<sup>3</sup> The third type of variable, an outcome of the first and the second sets of variables, measures production efficiency. Models that incorporate these three types of variables to study household decision-making in agriculture are few.

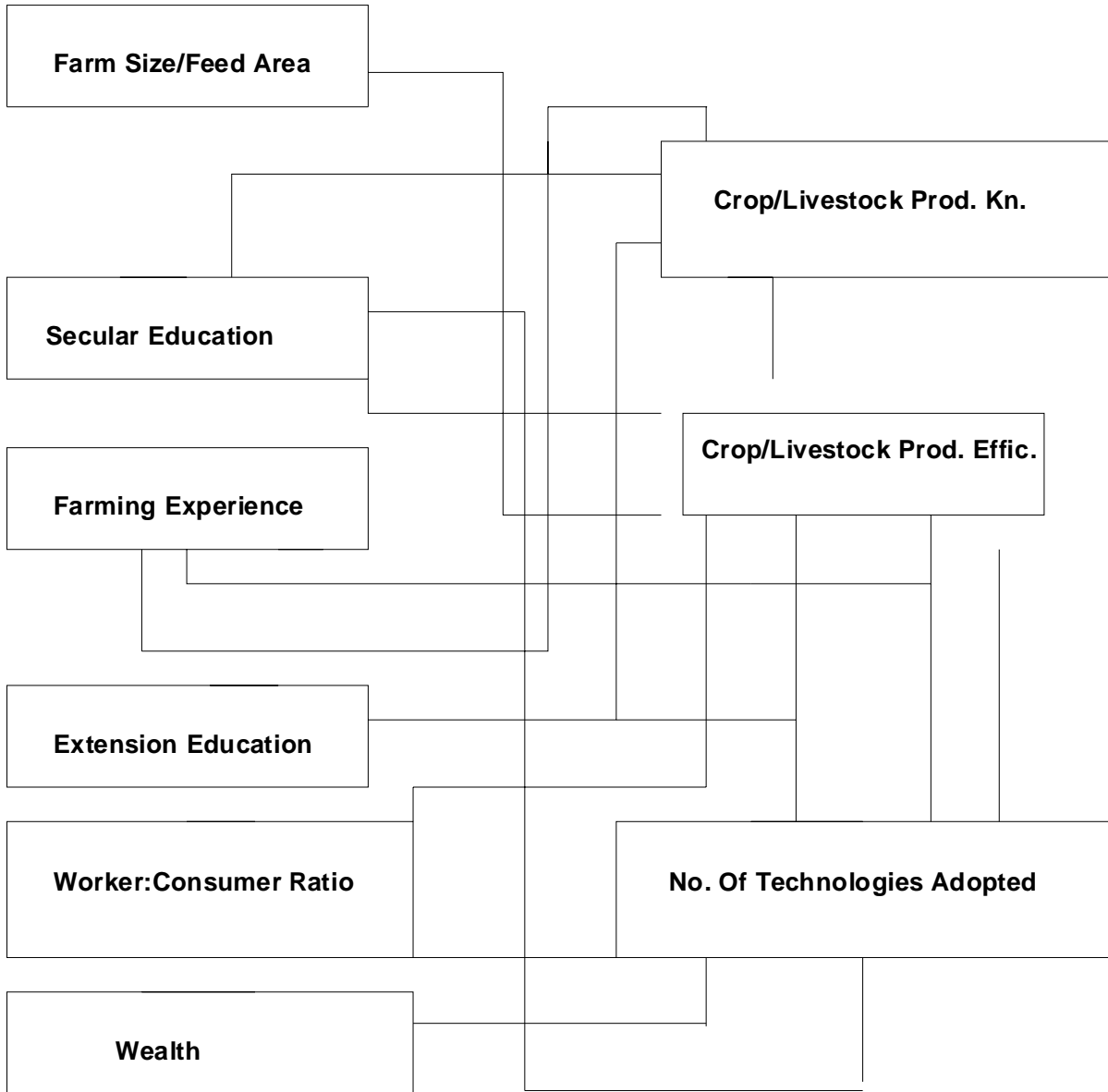
The present study hypothesizes that the impact of inputs on the efficiency with which output is produced would be greater among farmers who have adopted technologies which rank high in their list of strategies (e.g., fertilizer and pesticides) to secure subsistence requirement regardless of the conditions for technological optimality. Furthermore, this study investigates the impact of a single or selected combinations of technologies on production efficiency. Evidence

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<sup>3</sup> In this context, exogenous variables refer to factors that, given the structure of the model, determine the value or magnitude of another (output, decision or endogenous) variable. It must be noted, however, that in this simple conceptual framework, structural relationships between exogenous variables, and bi-directional relationships between exogenous and endogenous variables are excluded. This is primarily because of the requirements of the statistical analysis and to ease the interpretation of relationships between variables (see Kebede, 1993).

**Fig.1. Socioeconomic Variables and Production**

**Efficiency: A Testable Model**



on these and related questions help to formulate "appropriate" agricultural policies and research programs in crop and livestock production that may help to attain increases in food production.

### **The Study Sites**

The research was carried out over a period of 17 months in 1990-1991. The research sites are Selale and Ada districts of the central Ethiopian highlands. These two sites have similar farming systems and belong to the high potential cereal-livestock zone ( Kebede, 1993; FINNIDA,1989).

Selale is representative of the high altitude zone (more than 2000 meters above sea level) of the country. The major crops grown in Selale include oats, teff, barley, wheat, horse beans and field peas. The average farm size is 3.1 hectares, 30% of which is used as permanent pasture or grazing land with the rest cultivated. The average livestock holding is 3.5 cows, 1.8 oxen, 0.55 bulls, 1.8 young animals and 2.96 calves (FINNIDA, 1989). Farmers have extensive experience in livestock production and the region has greater potential for increasing productivity of this enterprise than the Ada region.

Ada is characterized by mild weather and represents the country's large middle-altitude cropping zone (1500 to 2000 meters). The major crops grown include teff, wheat, barley, horse beans, chickpeas and field peas. The average farm size is 2.6 hectares. There is virtually no fallow land. The average livestock holding is 1.28 cows, 1.98 oxen, 0.50 bulls, 0.53 young animals and 0.84 calves (Gryseels and Anderson, 1983). Compared with the Selale region, Ada farmers specialize more in crop than in livestock production. Farmers in this region have extensive experience in crop production. Selected socio-economic characteristics of farmers in both study sites is presented in Table 1.



Test for significant differences between socioeconomic profiles suggest that the two regions exhibit statistically significant differences with respect to the: I) number of household members who are independent, ii) number of years of education, iii) number of years of farming experience an independent farmer, iv) number of livestock owned, vi) average income received from the sale of grain, livestock and fuel wood, vii) crop and grazing area, viii) amount of milk produced per household, and ix) amount of grain produced (Table 1).<sup>4</sup>

Ada farmers had more years of schooling and more years of farming experience. They gain most of their income from the sale of grain while that of Selale farmers from livestock and livestock products. The productivity of dairy cows (litres/month) is higher among Selale farmers while Ada farmers produce greater crop yields per hectare.

### **Design of the Study**

Several crop production technologies are introduced in the study sites since the 1960's. However, introduction of cross-bred cows took place not only recently but also implemented by different agencies with relatively different approaches to technological introduction. Furthermore, this research was conducted to provide information on the socioeconomic feasibility of cross-bred cows. Therefore, it was felt appropriate to compare farmers who have adopted cross-bred cows (test) and those who did not (Control). These farmers may have adopted any combination of crop-production augmenting technologies.

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<sup>4</sup> Household members who are capable of working without supervision are categorized as independent or "workers" (age 15-60) and those who have to be supervised are considered dependent or "consumers" (age <15 and >60).

Table 1: Selected Characteristics of Selale and AdaFarmers

		Selale		Ada		F-Value	Prob>F <sup>1/</sup>
		N	Average	N	Average		
No. of Household Members who are:	Dependent	173	4.47	41	4.29	0.412	0.469
	Independent	207	1.75	48	1.5	4.52	0.03*
Education of Household Head (yrs)		55	2.5	23	3.6	5.671	0.001*
Experience (years):	Dependent	176	11.24	50	13.44	0.044	0.83
	Independent	176	24.58	50	27.88	4.173	0.04**
Income (Ethiopian birr) from Sale of:	Grain	203	230.27	49	828.6	65.46	0.006*
	Livestock & Livestock Products	194	451.4	22	203.11	1.09	0.058**
	Fuel wood	169	343.58	31	63.97	13.84	0.004*
Expenses (Ethiopian birr) for	Purchase of food	214	268.2	50	228.14	2.366	0.125
	Clothing	205	114.49	39	106.09	0.309	0.579
Milk production (in liters) per Month:	Local cows	193	56.9	35	42.6	6.79	0.05**
	Cross-bred cows	66	320.35	14	186.29	5.76	0.011*
Area under (hectares)	Crop	217	2.5	52	2.3	19.56	0.001*
	Grazing	208	0.8	37	0.2	26.29	0.006*
Livestock Number		165	10.89	16	5.18	0.69	0.016*
Crop Production ('00kg)		217	14.88	52	21.41	2.98	0.05**

1/ \* and \*\* refer significance at 1 and 5 percent respectively; the F-values test differences in the average values of socioeconomic characteristics between Selale and Ada farmers.

Households which received cross-bred cows and were selected for this study in the Ada and Selale areas numbered 26 and 89 respectively.<sup>5</sup> A confidence level of 95%, coefficient of variation of crop and milk yields of 96 percent and precision level of  $\pm 20\%$  resulted in a sample size of 89 farmers for the Selale region. For the Ada region, however, time and financial resources limit the number of test farmers to only 26. Comparison of average values of socioeconomic variables derived from a district-wide survey by the Ministry of Agriculture and average values of similar socioeconomic characteristics calculated from test farmers showed that the two data set are approximately the same. Therefore, the small sample size for the Ada region will not bias the foregoing analysis.

After determining the sample size, the need to use farmers who joined various programs as test groups necessitated the use of systematic selection of the control group.<sup>6</sup> A method was designed such that all test farmers were compared with farmers who exhibit similar socioeconomic characteristics (control farmers) but were different in ownership of cows (for details see Kebede,1993).

The control farmers were to have a comparable number of oxen, cows, sheep/goat, family size, age (farming experience), education, annual farm income and farm size (crop and grazing)

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<sup>5</sup> Prior to selection of the control group, the sample size was determined according to the following procedure. The sample size (N) is given as:  $N = (KV)^2/D^2$ , where D is the largest acceptable difference (in percent) between the estimated sample and the true population parameters. K is a measure of confidence (in terms of the number of deviations from mean) with which it can be stated that the result lies within the range represented by plus or minus D and V is the coefficient of variation of yields.

<sup>6</sup> The programs in question were those operated by the International Livestock Centre for Africa (ILCA), FINNIDA (Finnish International development Agency) and MOA (Ministry of Agriculture, Ethiopia).

with the test farmers. Moreover, the two groups had to exhibit similar ethnic, climatic and geographical characteristics. To accomplish this task, a three-step procedure was followed. Firstly, a group of farmers involving political leaders and elders in each peasant association were asked questions such as, "With whom do you think farmer "A" compares with respect to income, livestock holdings, living standard, etc., except that he does not own cross-bred cows?".<sup>7</sup>

Secondly, each test farmer was asked questions such as, "To whom do you think you are comparable with respect to income, livestock holding, family size, etc., except that you own cross-bred cows and the other farmer does not?". This method of identify a control farmer is difficult and socially controversial.<sup>8</sup> Nevertheless, it would provide a clue to identifying control farmers.

Thirdly, 150 farmers who did not receive cross bred cows were interviewed with respect to the above socioeconomic characteristics. The results were compared with background socioeconomic data obtained from test farmers. Combination of the above three steps enabled identification of control farmers that were used in the present study.

Selale farmers were instructed that inputs necessary for the management of cross-bred cows were available in their locality, and that they should take full responsibility for the management of such cows. Farmers in the Ada area, however, joined the ILCA technology diffusion program voluntarily because it provided a relatively risk-free environment (e.g.,

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<sup>7</sup> A peasant association is a geopolitically delimited association of peasants covering an area of about 400 hectares. Political leaders are farmers who, through democratic election processes, were elected to take administrative positions within a peasant association.

<sup>8</sup> Evaluating the economic well-being of other farmers would force farmers to think as if they were intruding into private life of others. This is not a socially acceptable norm. However, options were explored with groups of farmers and they suggested that this method could be feasible if used in conjunction with step one.

subsidized cost of feed). The approach to diffusion of technologies in the Selale region, therefore, is different from that implemented in Ada area. Comparative analysis of the two sites is hypothesized to reveal significant differences in the impact of socioeconomic variables on adoption of agricultural technologies and the resulting efficiency of production.

**The Theoretical Model**

Structural equation models have been used in several areas of the social and behavioural sciences (Joreskog and Sorbom, 1989). A structural equation model can be used to examine a phenomenon in terms of cause-effect variables and their indicators. Equations in this model represent a causal link and estimates of structural parameters may not coincide with the coefficients obtained from ordinary regression analysis. Structural parameters represent a relatively "accurate" features of the mechanism that generates the observed variables (Joreskog and Sorbom, 1989). Moreover, the linear structural relations model is designed to overcome problems associated with measurement errors and causal relationships.

The LISREL model chosen in this study is used to examine linear causal relationship (path analysis) between independent (exogenous) and dependent (endogenous) variables. Consider random vectors  $\eta = (\eta_1, \dots, \eta_m)$  and  $\zeta = (\zeta_1, \dots, \zeta_n)$  of latent dependent and independent variables, respectively. The linear structural equation can be specified as :

$$\eta = \beta\eta + \Gamma\zeta + \epsilon \quad \dots\dots\dots (1)$$

where  $\eta$  and  $\zeta$  are vectors of latent dependent and independent variables,  $\beta$  (mxm) and  $\Gamma$  (mxn) are coefficient matrices and  $\epsilon$  ( $\epsilon_1, \dots, \epsilon_m$ ) is a random vector of residuals. The elements of  $\beta$  represent the direct effects of  $\eta$ -variables on other  $\eta$ -variables, and the elements of  $\Gamma$  represent

direct effects of  $\zeta$  variables on  $\eta$ -variables.

Vectors  $\eta$  and  $\zeta$  are not observed, but instead vectors  $Y'$  ( $y_1, \dots, Y_p$ ) and  $X'$  ( $x_1, \dots, x_n$ ) are observed, such that

$$Y = \Omega_y \eta + u \quad \dots\dots\dots (2)$$

$$X = \Omega_x \zeta + \delta \quad \dots\dots\dots (3)$$

where  $u$  and  $\delta$  are vectors of uncorrelated error terms (errors of measurement between sets but may be correlated within sets). These equations represent the multivariate regressions of  $y$  on  $\eta$  and of  $x$  on  $\zeta$ , respectively.

The full LISREL model is defined by the following three equations:

$$\text{Structural Equation Model: } \eta = \beta \eta + \Gamma \zeta + \epsilon \quad \dots\dots\dots (4)$$

$$\text{Measurement Model for } Y : Y = \Omega_y \eta + u \quad \dots\dots\dots (5)$$

$$\text{Measurement Model for } X : X = \Omega_x \zeta + \delta \quad \dots\dots\dots (6)$$

These equations assumes that  $\zeta$  and  $\epsilon, \eta$  and  $u, \zeta$  and  $\delta$  are uncorrelated,  $\epsilon, u$  and  $\delta$  are mutually uncorrelated and that  $\beta$  has zeros is the diagonal and  $I - \beta$  is non-singular ( Joreskog and Sorbom, 1989).

Identification and estimation of parameters of structural equation models depends on forms of  $\beta$  and  $\Gamma$ . Three forms of  $\beta$  can be distinguished: diagonal matrix, triangular and unrestricted elements above and below the diagonal (Joreskog and Sorbom, 1989).

The data set from Ada and Selale regions in Ethiopia contains only observed variables and assumed zero measurement error. Thus, the LISREL model can be formulated as:

$$Y = \beta y + \Gamma x + \epsilon \quad \dots\dots\dots (7)$$

This is a structural equation model or a path analysis for directly observed variables. The  $y$ 's are to be explained by the model. That is variations and covariations among the  $y$ -variables are to be

accounted for by the x-variables. The x-variables may be random variables or a set of fixed values. The parameter matrices involved in this model are  $\beta$ ,  $\Gamma$  and  $\Phi = \text{cov}(\hat{\epsilon})$ . A special case of this model is that when  $\beta$  is sub-diagonal and  $\Phi$  is diagonal, the structural equation for observed variables model is called a recursive system or path analysis. Path analysis involves two kinds of variables: independent or cause variables  $x_1, x_2, \dots, x_n$ , and dependent or effect variables  $y_1, y_2, \dots, y_p$ . Models of this type and estimation techniques in econometrics can be found in Theil (1971) and Goldberger (1971).

Estimation of path analysis for directly observed variables using LISREL can be carried out using a system of equations to estimate all structural parameters directly. The structural equations include: specification of the data type (raw, covariance, correlation), the model (the number of x and y variables, and the form of the matrices of data) and an output statement (for the details see, Joreskog, et al. 1989).

Specification of all kinds of relationships between x's, x's and y's, and between y's for all conceivable variables may result in a lack of convergence even with increases in the number of iterations (Joreskog, et al. 1989; Saris, et al. 1984; Hayduk, 1987). In the study of Ada and Selale farmers, based on regression analysis and prior results from group discussions, x-variables whose effect on the y's are relatively low are excluded from the analysis. Two types of models are estimated. One with five and three, and another with six and three exogenous and endogenous variables respectively.

## **Description of Variables**

The exogenous variables include wealth (in Ethiopian birr), worker:consumer ratio, farming experience (years), number of days a farmer receive training or information from extension agents, number of years of secular education and farm or feed area (hectares). The endogenous variables include livestock or crop production knowledge, number of technologies adopted and relative production efficiency. Analysis is performed by region, and within a region by control and test groups.

Wealth is defined as the market value of grain, milk and its byproducts, and live animals. The worker:consumer ratio is taken as the ratio of the number of household members capable of working without supervision ( age 15-60) to members who require supervision ( age <15 and >60). Measures of production efficiency scores were computed from stochastic frontier production function analysis (Kebede, 1993).

There is no hard and fast rule to measure or quantify production knowledge. Studies in cognitive psychology have demonstrated the usefulness of measuring knowledge using problem solving tests or comprehension ability (see Eisemon, 1988;Bransford and McCarrel, 1983).

Problem solving tests were constructed to measure agricultural knowledge and skills related to current production technologies and practices. The tests were intended to examine the kinds of solutions households provide to crop and livestock production problems. Answers from problem solving tests were scored to compare variations in knowledge of farmers within and between regions. The basis for scoring were answers obtained from group discussions with farmers of different age-groups. The premise behind this basis for scoring was that experience and indigenous knowledge vary by age. Answers from group consensus were believed to reflect



solutions to actual problems of farming in the study regions. A score of 1 to 10 was prepared and individual farmers responses were ranked relative to the answers given by the group ( see Kebede, 1993).

## **Empirical Results**

The LISREL model was formulated for a large number of variables. However, it was not possible to attain statistical convergence. The estimates were not statistically acceptable, as indicated by large values of standard errors and beta coefficients, negative degrees of freedom and very high chi-square values (see Joreskog and Sorbom, 1989).

The influence of social networks and macro-integrating forces (e.g., markets, schools and institutions) is reflected in differential access to physical resources and knowledge, changes in economic and social status. It appears reasonable to include these and other socio-economic variables in the LISREL model. The difficulty of testing the LISREL model with all variables that influence the processes and consequences of household decision-making necessitated choosing variables that satisfy specific criteria. Variables included in the LISREL model are those that: I) are essential to the production of both grain and livestock (e.g., land, feed area and worker:consumer ratio); ii) influence management style or human capital; and iii) reflect influences from differential access to resources and institutions (e.g., wealth).

Three LISREL models are analyzed. Model I includes exogenous variables such as farm size, secular education, farming experience, extension education and worker:consumer ratios, and endogenous variables such as crop production knowledge, number of technologies adopted and crop production efficiency. The analysis is carried out by region, and within a region by test

and control farmers. Model II is specified similarly to Model I except that wealth (as a proxy that reflect the influence of factors that determine access to resources such as grazing and crop area) is added to the analysis. Model III presents results from LISREL analysis with variables similar to those in Model II but for Ada and Selale regions without categorizing farmers into test and control groups.

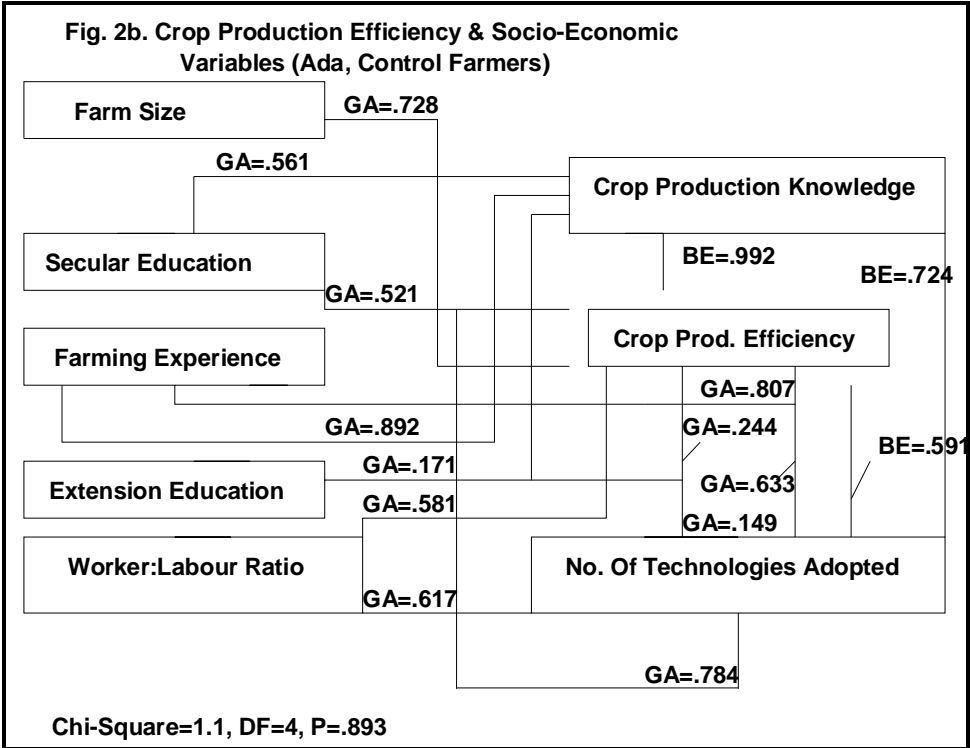
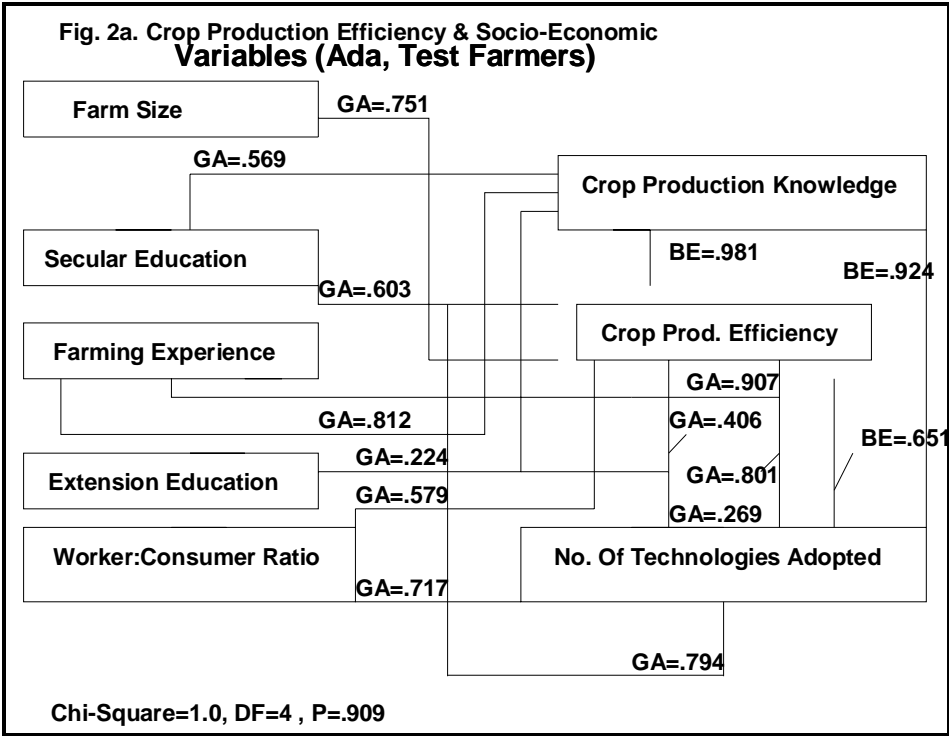
### **Results from Model I**

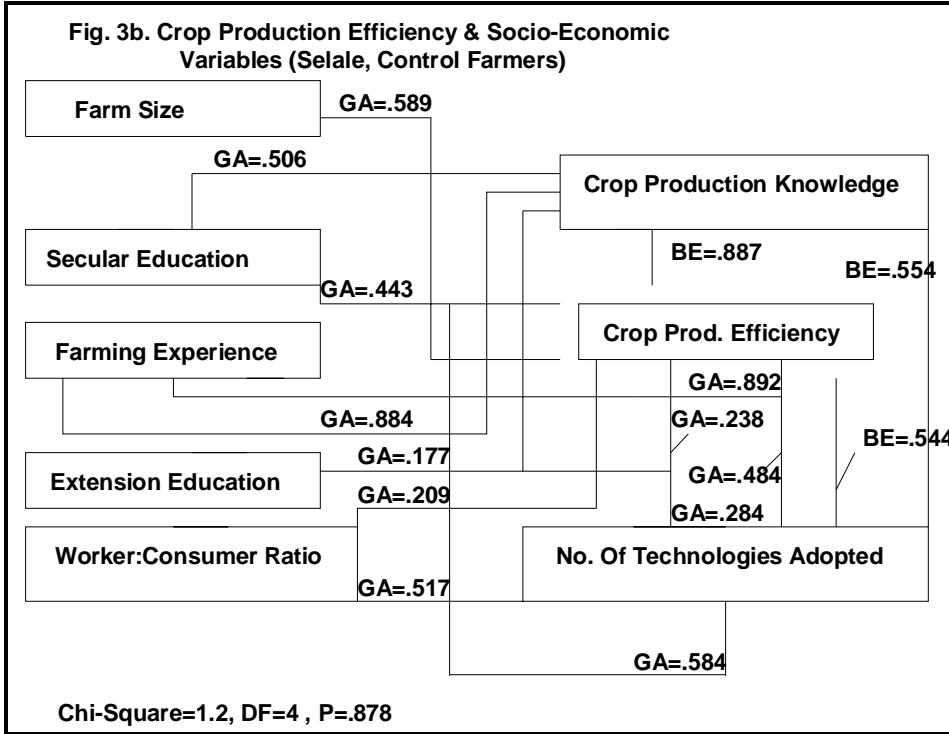
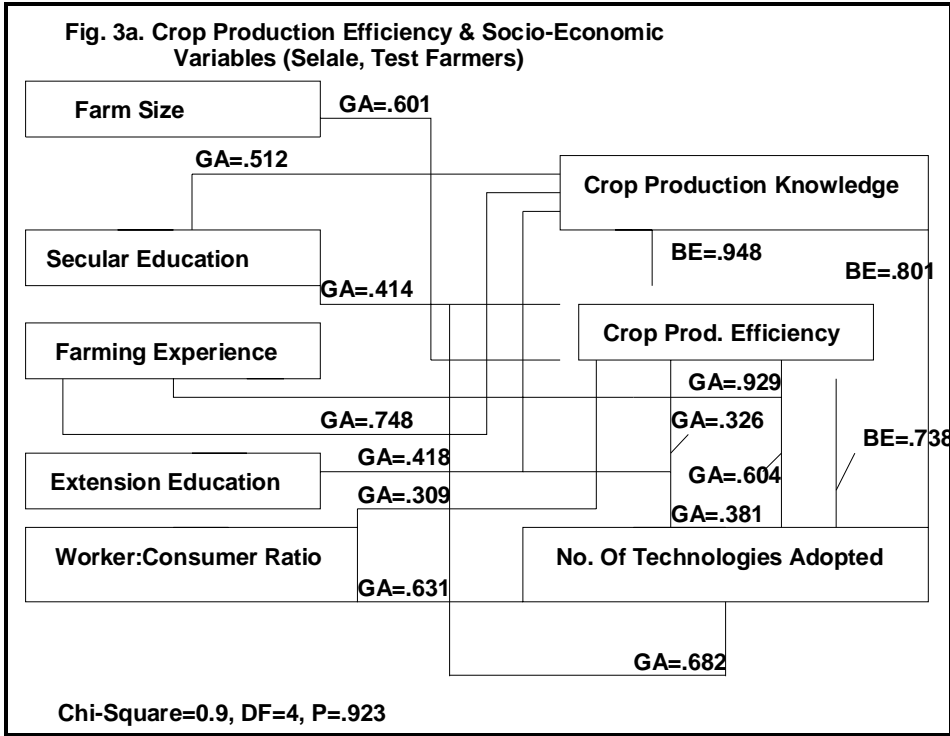
The results of the analysis of causal relationships between exogenous and endogenous variables for test and control farmers of the Ada region are presented in Figures 2a and b. The results indicate that endogenous variables (e.g., production knowledge, number of technologies adopted and crop production efficiency) are positively influenced by most exogenous variables.<sup>9</sup> Production knowledge, farming experience and extension education exert relatively larger impacts on the number of technologies adopted and crop production efficiency of test compared to control farmers. The chi-square values of the model is smaller, that is the probability of obtaining a higher chi-square value is very low. It means that this is the best model to represent the conceptual framework depicted by Figure 1.

LISREL analysis similar to that of Figures 2a and b for the Selale region is presented in Figures 3a and b. The results show that the number of technologies adopted, farm size,

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<sup>9</sup> The beta coefficient (BE) indicate the effect of one endogenous variable on another, while the gamma coefficient (GA) indicate the effect of an exogenous variable on an endogenous variable.





production knowledge, experience, extension education, and worker:consumer ratio exert larger and positive influences on crop production efficiency of test compared to control farmers.

Worker:consumer ratio, extension education, production knowledge, and experience greatly influence the number of technologies adopted by test compared to control farmers of the Selale region. Comparison of Figures 2a and b, and 3a and b indicates that relatively more variables exert greater influences on adoption decisions and production efficiency of test compared to control farmers. Moreover, comparison of test and control farmers indicate that differences in the impact of crop production knowledge and number of technologies adopted on production efficiency are minimal among farmers in the Ada than Selale region.

Farm size is the most important single input for both crop and livestock production. The average farm size is fixed according to family size. Households are given user rights to land (Kebede, 1993). The absence of ownership right has reduced the incentive of households to invest in land. In spite of this uncertainty, the contribution of land to crop production efficiency is high. The impacts of land and worker:consumer ratio are relatively higher among test compared to control farmers in both study sites.

One of the most important factors shaping the structure, function and decision-making processes of households is experiential knowledge. This knowledge is both a social and an individual product (see Kebede, 1993). The statistical result suggest that secular education and experience contribute significantly to crop production knowledge compared to extension education.

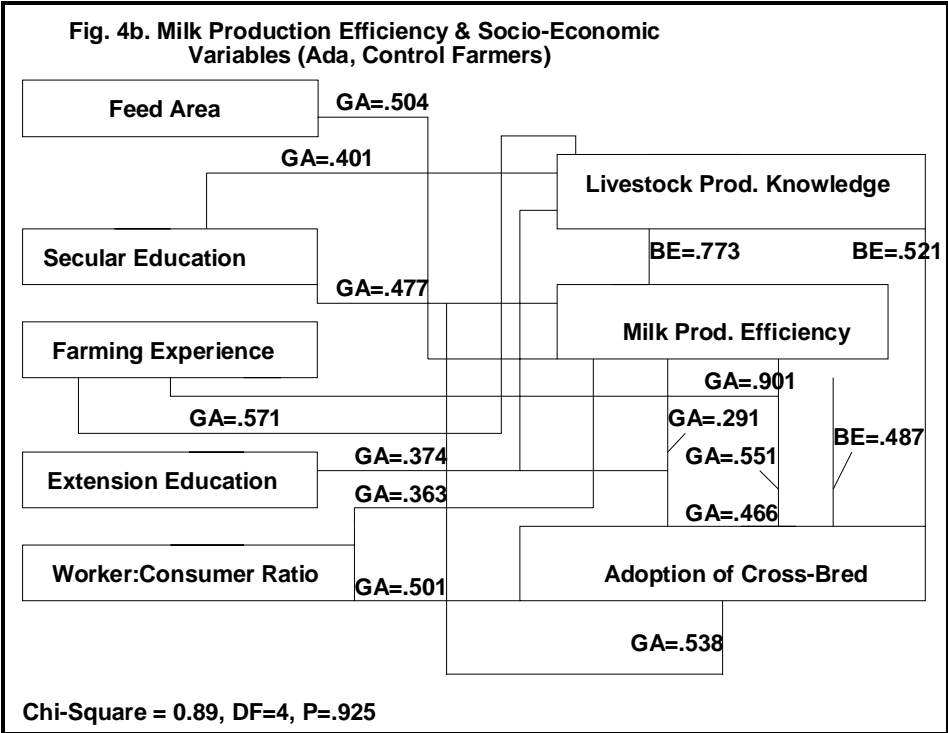
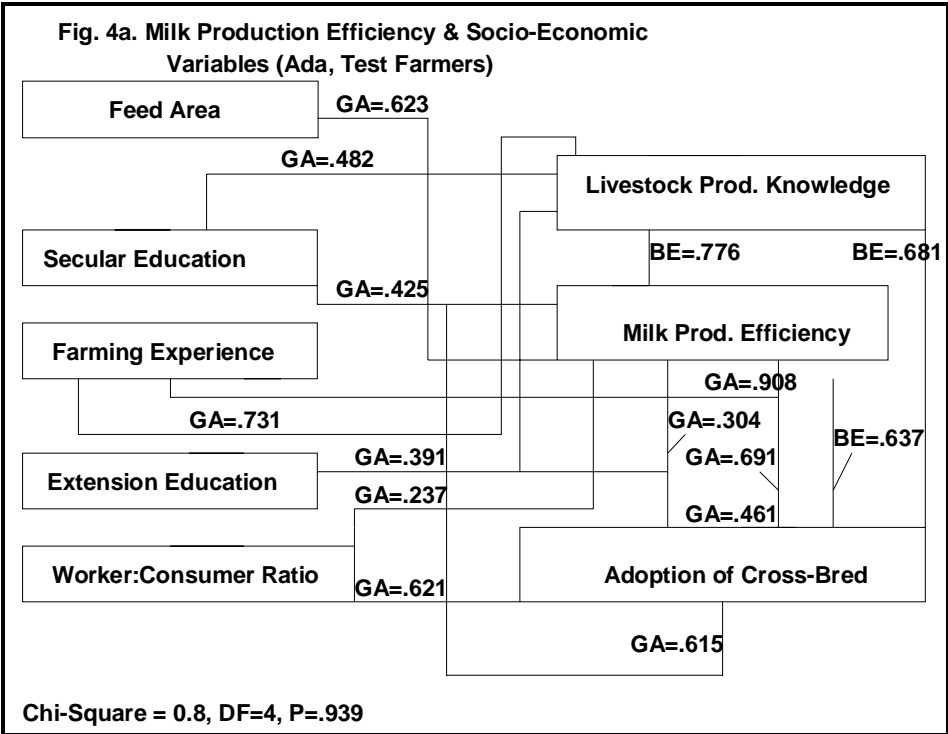
The contributions of secular education and experience to decisions regarding adoption of innovations and on crop production efficiency are consistently larger than other variables. Human capital, comprised of components such as vocational training, experience and skills from secular or sacred education, influences the capacity of economic agents to adjust to changes in the environment. Land-specific experience is an important factor affecting efficiency, where physical differences between parcels of plots are substantial. Location-specific experience influences the choice of farm adjustment mechanisms. If the contents of educational curricula is held constant, farmers with land, enterprise, and location-specific experience will have an extra advantage in adjusting to changes facing agriculture (Ekanayake and Jayasuriya, 1989). As the results of this study suggest, crop production knowledge exerts significantly larger influences on crop production efficiency in the Ada compared to Selale region. In a similar vein, the effect of livestock production knowledge on milk production efficiency is higher among Selale producers than those in Ada.

The effect of extension education is not as great as that of secular education or production knowledge. Becker (1990) argues that because weak adoption of yield-increasing technologies is explained by different opportunity costs for the labour-time spent by family members, special extension programmes for family members with low off-farm employment opportunities are required to increase adoption of innovations. In the Ada and Selale regions, households have limited off-farm activities for self-employment. Thus, strengthening extension education to help producers understand innovations and to encourage investment in income-generating activities such as gardening and craft production may contribute to greater success in adoption of innovations and to increased production efficiency (see also Kebede, et al., 1990).

Several studies have demonstrated that, with increases in the number of consuming units within a household (low worker:consumer ratio), not only does production decline but also the probability of adoption of innovations may decrease (Feder, et al., 1985; Molnar and Clonts, 1983; Barlett, 1980). Conversely, with increases in the worker:consumer ratio, not only does the probability of adoption of innovations but also the efficiency with which they are used may increase. The results from Ada and Selale regions suggest that there may be a relatively moderate effect of the worker:consumer ratio on the number of technologies adopted and efficiency scores. If all the variables are grouped into physical (land and labour), skill (extension education, secular education, production knowledge and experience), and technologies, the combined effect of physical factors on production efficiency is less than skill or knowledge variables and technologies. The impact of variables on production efficiency, in ascending order, can be summarized as: physical factors, technologies and knowledge variables.

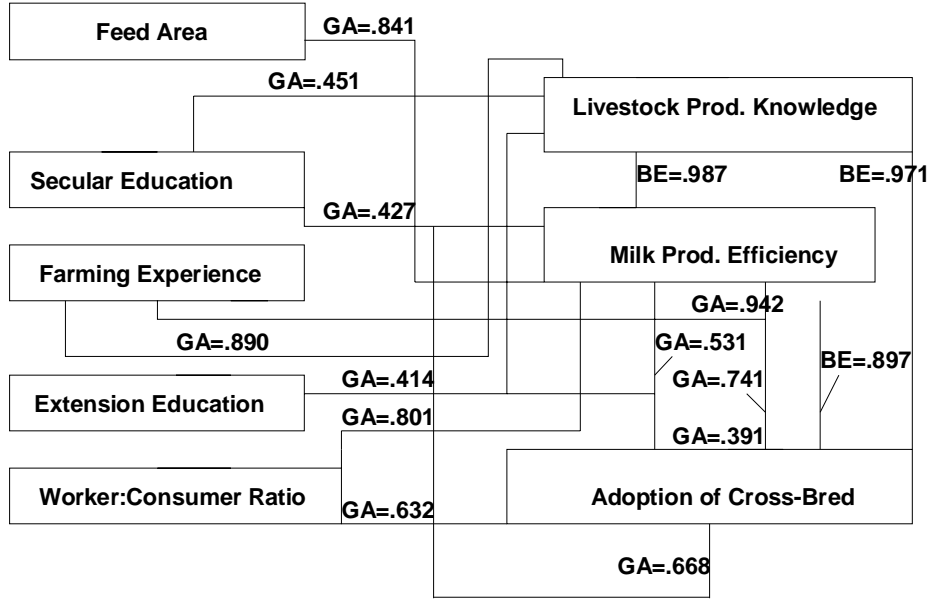
The conceptual framework for milk production efficiency for the test and control farmers of the Ada region are presented in Figures 4a and b respectively. The results indicate that feed area and worker:consumer ratio exert larger influences on milk production efficiency. Secular education and the worker:consumer ratio greatly influence decisions to adopt cross-bred cows among test compared to control farmers of the Ada region.

The results of LISREL analysis for causal relationship shown in Figures 4a and b for the Selale region are presented in Figures 5a and b. The results indicate that adoption of cross-bred cows, feed area and experience greatly influence milk production efficiency of test compared to



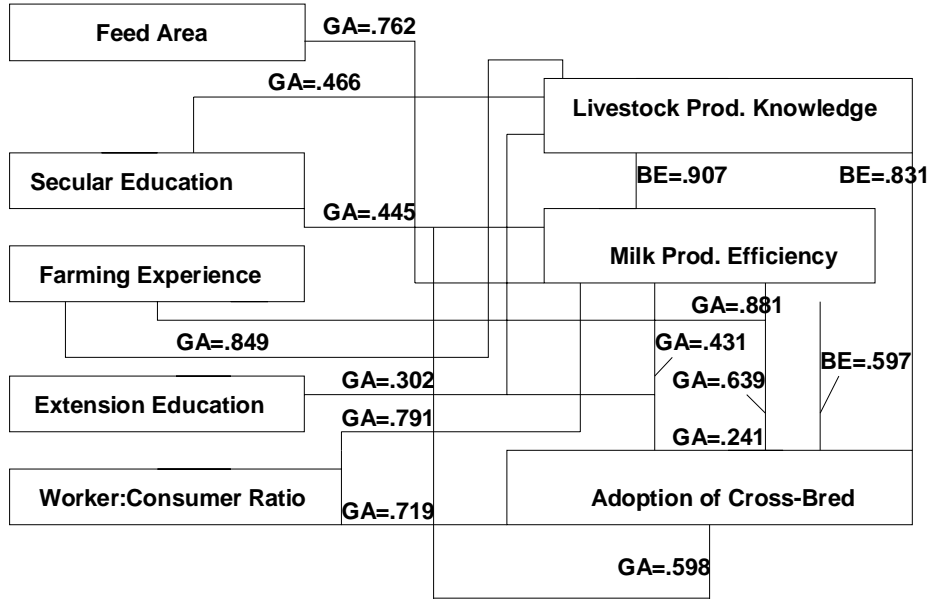


**Fig. 5a. Milk Production Efficiency & Socio-Economic Variables (Selale, Test Farmers)**



Chi-Square = 3.4, DF=4, P=.495

**Fig. 5b. Milk Production Efficiency & Socio-Economic Variables (Selale, Control Farmers)**



Chi-Square = 4.4, DF=4, P=.356

control farmers. Extension education, secular education and production knowledge exert larger influences on decisions regarding adoption of cross-bred cows.

Differences in the models of crop and livestock production efficiency can be seen with respect to pre-conditions or "modernization" conditions and the resource potentials of the two study sites. Technology transfer with the help of extension agents can produce positive results (Feder, et al. 1985). This study argues that in fact it is only when modernization conditions (for example milk collection centres, access to high demand centres, veterinary and artificial insemination or bull services for milk production technology) are combined with adequate resource base (e.g., abundant source of feed) that extension services contribute to increases in milk production efficiency. For example, Ada is located near urban centres and marketing services. However, there is neither adequate grazing area nor cheaper ways of obtaining feed for milking cows. Selale, on the other hand, is located close to milk collection centres, has adequate sources of feed supply and is located relatively close to high milk demand centres. Thus, the impact of extension education on adoption of cross-bred cows and milk production efficiency is small in the Ada compared to Selale region.

Feed area exerts a larger influence on the milk production efficiency of Selale compared to Ada farmers. On the other hand, the contribution of farm size on crop production efficiency is larger among Ada compared to Selale farmers.

Previous findings in the study of household decision-making argued that households try to avoid drudgery associated with activities which do not remunerate labour (Durrenberger, 1984; Barlett, 1980). For example, rearing cross-bred cows may not be a profitable venture for Ada producers. Cross-bred cows require a lot of labour for milking, feeding, watering, veterinary

service and processing of milk into butter. The price of fresh milk is low. The amount of butter produced per litre of fresh milk from cross-bred cows is small compared to milk obtained from local cows. Thus, labour used in feeding, caring and processing milk of cross-bred cows may not be remunerated adequately. This factor, ceteris paribus, may also be the reason for smaller contribution of labour to milk production efficiency. The results from Figures 4a & b, and Figures 5a & b show that the worker:consumer ratio contributes less than skill variables, such as experience and production knowledge, and physical factors, such as grazing area, to milk production efficiency.

### **Results from Model II**

The second model involves the same set of exogenous and endogenous variables as the first model except that wealth is included (Kebede, 1993). The magnitude and direction of the contribution of knowledge variables (secular education, farming experience, production knowledge and extension education) for model II closely approximate results obtained from model I. With the exception of the impact of production knowledge, the effect of most exogenous variables is less than the values of the estimates obtained in the first model.

The magnitude of the impact of wealth on decisions to adopt technologies is consistently larger than the effect of other variables. This finding confirms the hypothesis that households which are wealthy will adopt innovations more readily than those who are not. Wealthy farmers have the means to accumulate more information, thereby capable of increasing their production

and marketing knowledge. Thus, they tend to be early adopters (Mason and Halter, 1980; Becker, 1990).<sup>10</sup> Regarding milk production model, the results compared to those presented in model I.

### **Results from Model III**

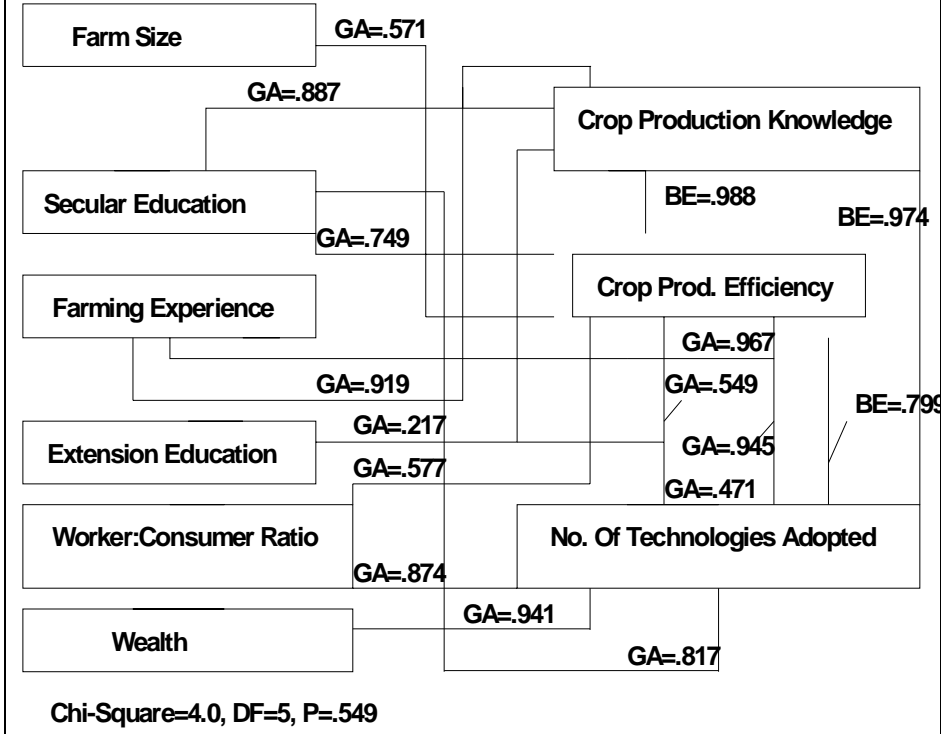
LISREL analyses for crop and livestock enterprises by region are presented in Figures 6a and b. The results of the crop production model suggest that production knowledge, experience, wealth and secular education exert larger influences on adoption decisions. Experience and secular education strongly influence production knowledge. Crop production efficiency is largely determined by production knowledge, experience and secular education. The outcomes from the milk production model indicate that wealth, experience, and production knowledge greatly influence decisions to adopt cross-bred cows. The impacts of production knowledge, secular education and experience on milk production efficiency are greater than that of other variables.

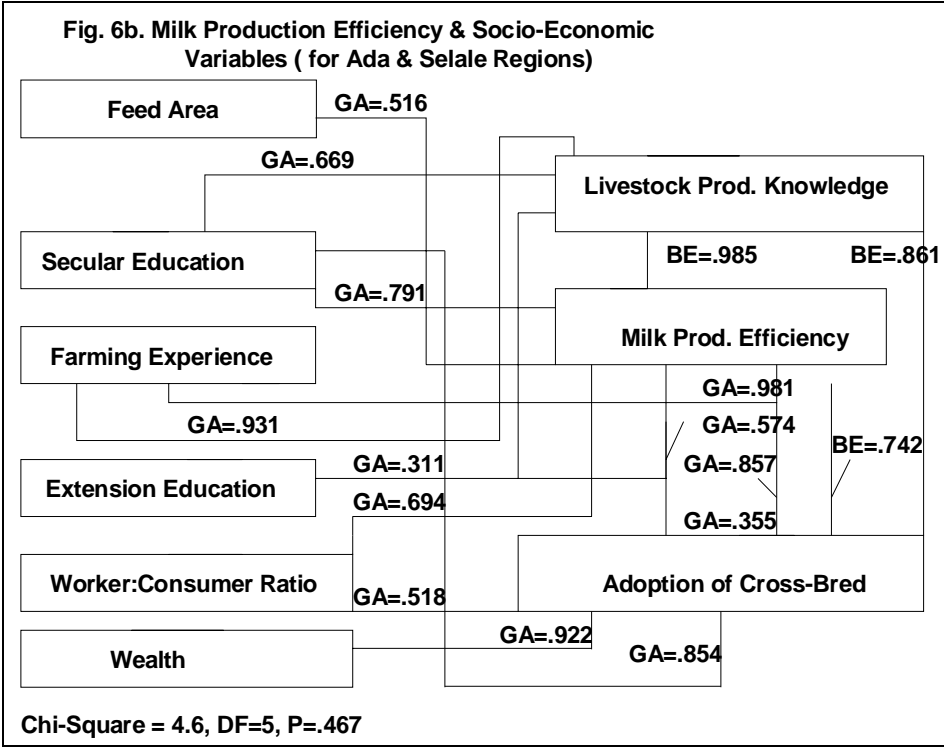
The results of model III consolidate the findings from models I and II. The impacts of farm and feed size are lesser, while those of education, experience, production knowledge and wealth are greater in model III compared to those obtained in models I and II. The probability of obtaining a chi-square value larger than what is found from this model is very low. The signs and magnitude of impacts of the estimates are acceptable. Thus, model III has performed quite well compared to models I and II.

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<sup>10</sup> Wealthy farmers tend to be closer to those with political influences, thus may have greater access to new technologies.

Fig. 6a. Crop Production Efficiency & Socio-Economic Variables (for Ada and Selale Regions)





## **Adoption of Mixes of Technologies and Production Efficiency**

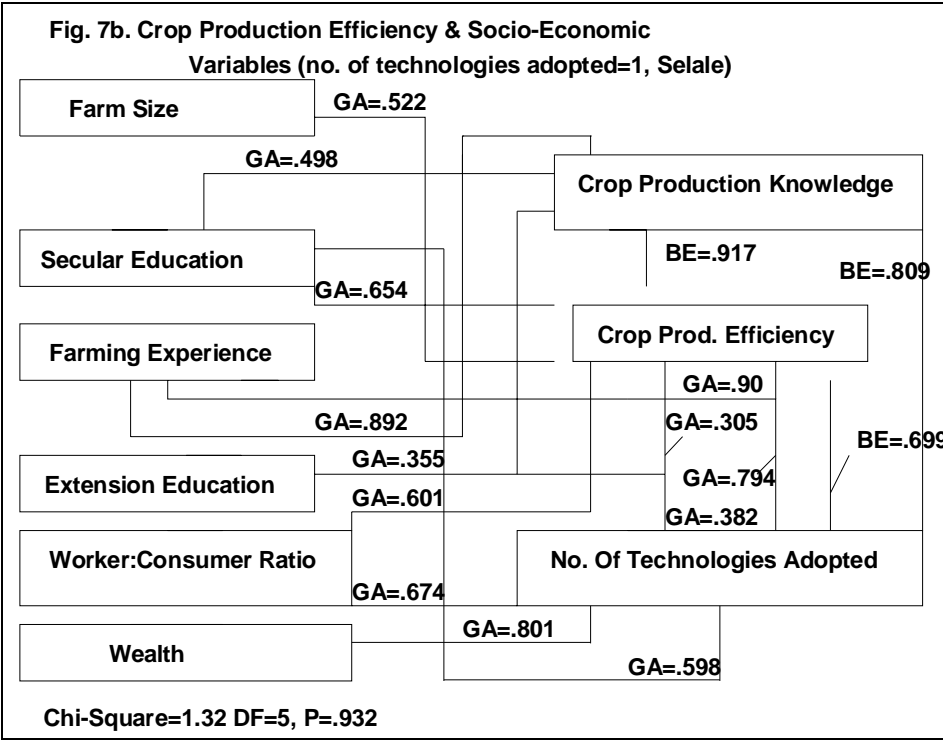
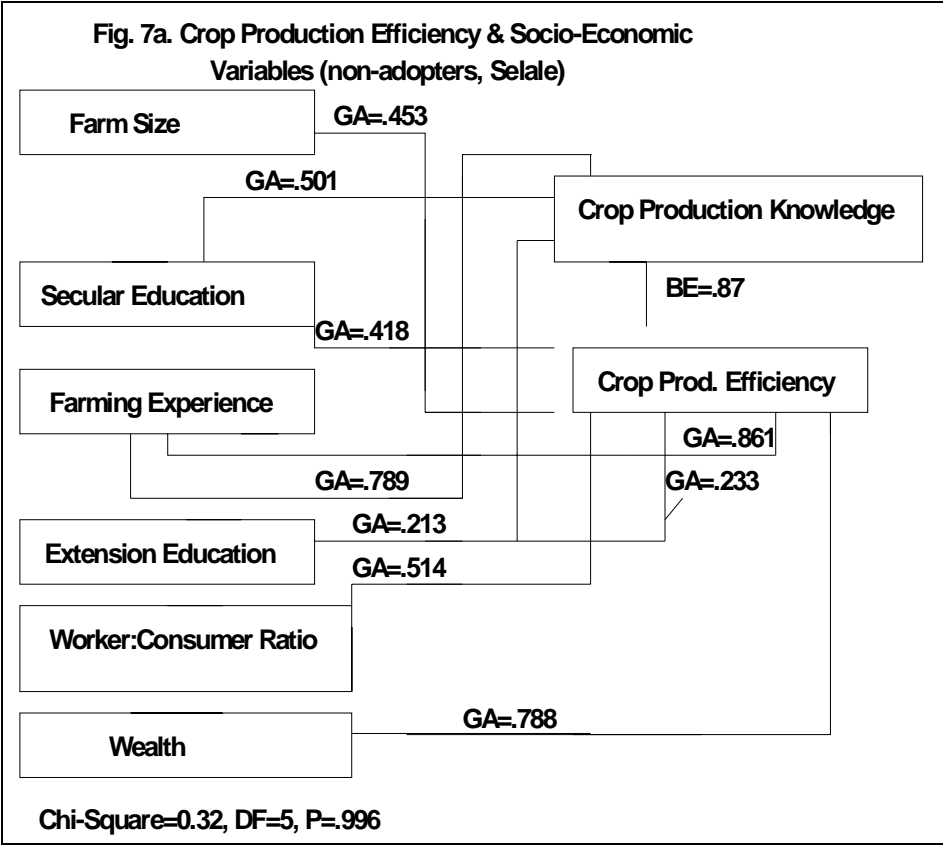
Households make strategic decisions in the adoption of selected mixes of new technologies. The manner in which they combine different innovations influences the efficiency of production (see Kebede, 1993).

A comprehensive examination of the effect of inputs on production efficiency among households who have adopted various mixes of innovation can be obtained from LISREL analysis. LISREL analysis was conducted for crop and milk production efficiency in both study sites. Specifically, analysis was performed for farmers who have not adopted new technologies, for those who have adopted one, two, three and four technologies. For the purpose of exposition only findings from crop production models for the Selale region are presented (see Figures 7a,7b,7c,7d and 7e). The results for crop and milk production model of Ada and milk production model for the Selale region can be found in Kebede (1993).

The findings of LISREL analysis indicated that the impact of inputs on the efficiency with which crops or milk are produced is higher when producers adopt at least two technologies. That is, producer who have adopted two or more innovations exhibit higher production efficiency compared to those who adopted none or a single technology. This corresponds to the gradient approach to technological innovation (see also Kebede, 1993).

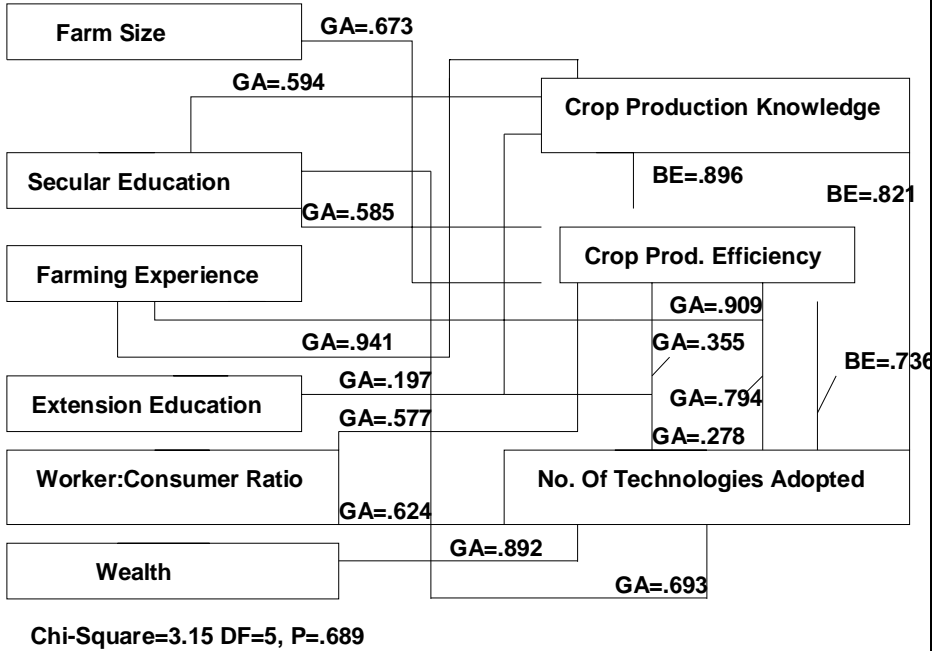
## **Summary**

The conceptual framework examined in this study incorporates variables that influence the processes and consequences of household decision-making. It includes the most important physical resources (e.g., land and labour), variables that reflect the consequences of interaction

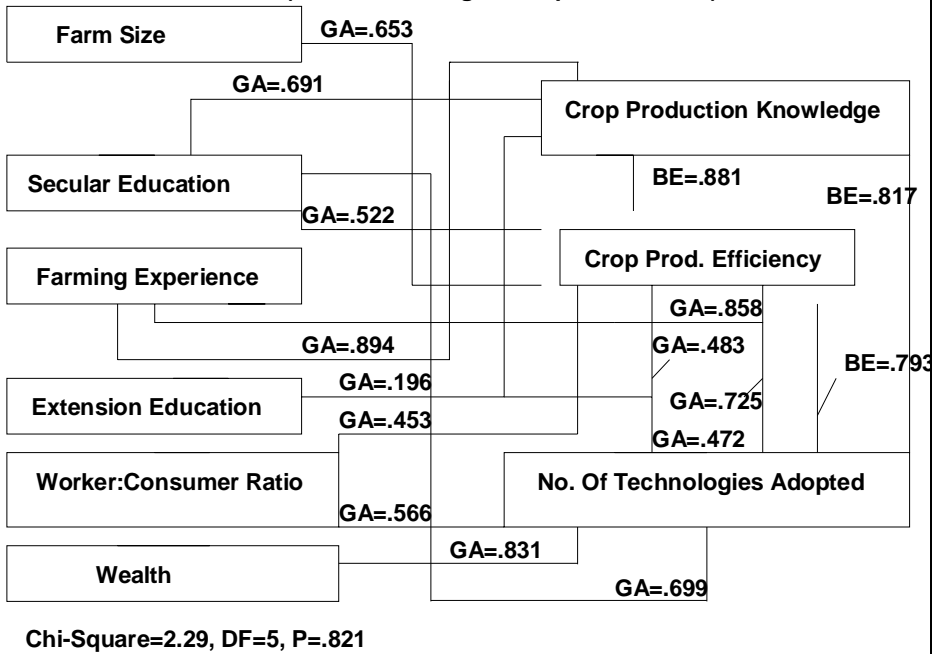




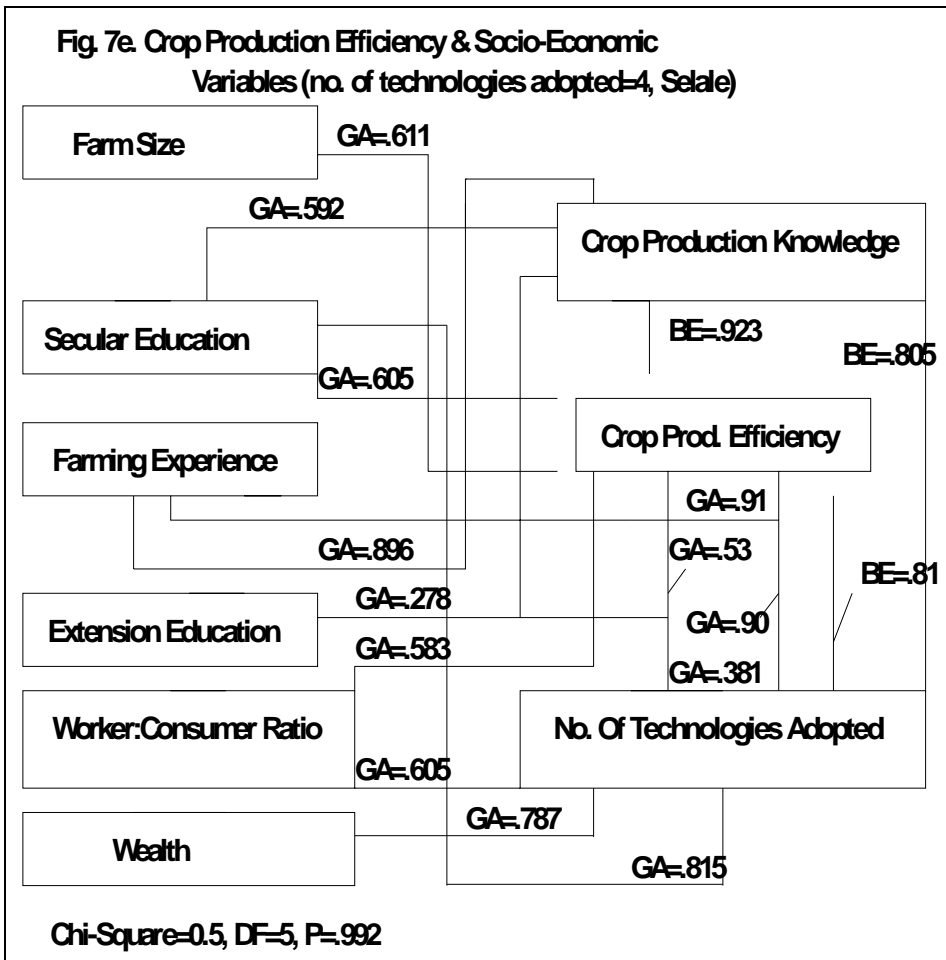
**Fig. 7c. Crop Production Efficiency & Socio-Economic Variables (no. of technologies adopted=2, Selale)**



**Fig. 7d. Crop Production Efficiency & Socio-Economic Variables (no. of technologies adopted=3, Selale)**



**Fig. 7e. Crop Production Efficiency & Socio-Economic Variables (no. of technologies adopted=4, Selale)**



between physical and non-physical resources such as institutions and markets (e.g. wealth and technology adoption), and measures of production efficiency.

The conceptual framework investigated by this study is found to be satisfactory in explaining the causal linkages between socioeconomic variables in the production efficiency models. The results from the LISREL analysis suggest that variables that are related to cognitive ability or skills of households make the largest contribution to crop and milk production efficiency compared to physical factors such as land. The contribution of variables to production efficiency can be summarized in the following descending order: skill variables (experience, production knowledge and secular education), technologies adopted, physical factors, and extension education. Furthermore, the analysis indicated that the impact of inputs on production efficiency is higher when producers adopt one or two technologies in the Selale region and two or more technologies in Ada region. This implies that, as opposed to the recommendation of package approach to technological introduction, selective mixes of technologies contribute to increases in production efficiency.

One of the problem faced by development projects in LDCs is to identify, given the scarcity financial and skill resources, aspects of households that should be targeted to ensure increases in food production. The findings of this study indicate that the processes and consequences of production decision-making can be greatly influenced if intervention strategies design methods that enhance and/or utilize skill variables (esp. indigenous knowledge).

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