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Acreage Allocation Model

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RR–84–20
OCTOBER 1984

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FARM SUPPLY RESPONSE IN KENYA: ACREAGE ALLOCATION MODEL

N.S.S. Narayana
Indian Statistical Institute, Bangalore, India

M.M. Shah
International Institute for Applied Systems Analysis, Laxenburg, Austria

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Reprinted from the *European Review of Agricultural Economics*, volume 11 (1984)

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Printed by Novographic, Vienna, Austria

FOREWORD

Understanding the nature and dimensions of the world food problem and the policies available to alleviate it has been the focal point of the IIASA National Agricultural Policies Program since it began in 1977.

National food systems are highly interdependent, and yet the major policy options exist at the national level. Therefore, to explore these options it is necessary both to develop policy models for national economies and to link them together by trade and capital transfers. For greater realism the models in this scheme are being kept descriptive rather than normative. Eventually it is proposed to link models of twenty countries, which together account for nearly 80 percent of important agricultural attributes such as area, production, population, exports, and imports.

A model for Kenya is being developed at IIASA. The model will provide a prototype for African developing countries with growing populations and emerging development problems.

This report presents the results of work on farm supply response in Kenya. As understanding farmers' behavior in response to various possible policy instruments is a critical part of much of agricultural policy analysis, this work explicitly considers the small-farm/large-farm structure of the Kenyan agricultural scene. The study provides a significant element of the IIASA agricultural policy model for Kenya.

KIRIT PARIKH
Leader
National Agricultural Policies Program

Farm supply response in Kenya: Acreage allocation model

N. S. S. NARAYANA and M. M. SHAH*

International Institute for Applied Systems Analysis, Laxenburg, Austria

(received November 1982; revision received March 1984)

Summary

Employing ARIMA estimations of expected prices and yields, Nerlovian response functions are estimated for large and small farms in Kenya. Results show that (expected) yield levels, rather than expected prices affect the supply response of small farms, whereas large farms react more strongly to prices.

1. Introduction

Agriculture is a major sector of the Kenyan economy. In order to make an appropriate policy analysis of Kenyan economic development, and, in particular of Kenyan agricultural development, it is essential to understand the effects of various policy instruments on the agricultural supply. This implies a detailed study of farmers' behaviour in allocating their limited lands to growing various crops, and their risk-taking entrepreneurship in an uncertain environment of future prices and yields and application of inputs such as fertilizer, capital, labour, etc.

In this paper, we aim to study the acreage response of Kenyan farmers. We believe that Kenyan farmers are rational, and, that they respond to various signals in the economy, and formulate their own expectations of the revenue they will obtain by growing different crops taking into account rainfall, soil conditions,

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* The cooperation of the Ministry of Agriculture and various marketing boards in Kenya and the Statistics Division, FAO, in making available data and information is highly appreciated.

The authors would also like to express their thanks to G. Fischer, K. S. Parikh, and T. N. Srinivasan for valuable comments and discussions.

We would also like to thank C. Enzlberger and L. Roggenland for patiently typing and retyping our manuscript.

Euro. R. Agr. Eco. 11 (1984), 085–105

0165-1587/84/0011-0085 $2.00

etc. All major crops (except coffee[1]) in Kenya are considered, and area response models are developed to allocate land to various crops. The study on the application of non-land inputs and the yield response is described in Fischer and Shah (1984a).

African farmers are rational. Alibaruho (1974) provides an excellent survey on this issue, and summarizes as follows: 'There has been a "positive" phase in which the issue has been to determine what African farmers do under different economic situations . . . and a "hypothesis testing" phase in which the issue has been to determine why African farmers do things the way they do'.

Many of the 'hypothesis testing' studies of African farmers may be divided into three categories, namely:

1. rational response to price changes,
2. inverse relationship between market surplus and price,
3. institutional constraints prohibiting any price response.

We believe that even an institutional constraint such as producing for self-consumption is very much a rational response, because it represents the farmer's choice in regard to what to sell (to make profits) and what to buy (for own consumption), given the knowledge of taxes, subsidies, trade margins and transport costs.

The rest of this section is devoted to describing the Kenyan agricultural scene, providing a brief review of the existing literature in the present context. In Section 2, we briefly present the traditional Nerlovian model for supply response followed by some methodological issues of our model. Details of the data base and the estimation procedure are also described. In Section 3, the results are given, and in Section 4, the policy considerations and conclusions of the study are presented.

1.1. *Kenyan agricultural sector*

Kenya's agricultural production roughly doubled over the last 20 years. In a number of ways, the agricultural sector in Kenya forms the backbone of the economy. First, more than 80% of the population derives its livelihood from this sector. Second, this sector accounts for more than 65% of the foreign exchange earnings of Kenya. This foreign exchange is essential for the imports of many non-competitive goods which are crucial for the rapid development of the Kenyan economy. During the period 1961 to 1976, the share of agriculture in total GDP fell from 42% to 38%, whereas the share of manufacturing rose from 9% to 12%.

In comparison to most other countries in tropical Africa, Kenya's agricultural sector is perhaps the most developed. For example, in this region, Kenya is the only country with land adjudication and registration. The intensity of land use and husbandry is higher than anywhere else in tropical Africa. However, the level of agricultural technology, though relatively sophisticated in comparison to most countries in the region, is well below the intensity of inputs required for meeting the future demands of agricultural products (Shah and Fischer, 1982). Food requirements are especially important in the light of the recent estimates of population growth, which show an increase of the order of 3.9% per annum (Kenya, 1979).

Agriculture in Kenya has a dual character. On one hand, there are nearly one and a half million small farms (Kenya, 1977), the majority (59%) less than 2 ha., and few (10%), more than 5 ha. in size. On the other hand, there are some three thousand large farms: 70% of these have an average size of 160 ha., and for the remaining 30%, the average size is about 2500 ha. Large farms in Kenya are reckoned as all farms of 8 hectares and above in the former 'scheduled' areas and the coastal strip which are included in the Annual Agricultural Census of Large Farms. The subdivided settlement farms are also considered as being large farms if they are operated as single compact units under cooperative management. In the present study, small farms are defined as all other farms.

Our approach is to model the supply response for small and large farms separately. The distinction between small and large farmers is an essential one from the viewpoint of policy analysis. Historically, many of the agricultural policies, and, in particular, producer price policies and trade policies were formulated on the basis of the large farms. But these policies could have had an important impact on the acreage response of small farms. Table 1 shows the acreages of the main crops on the small and large farms for the years 1963 (independence year) and 1975. The small-farm sector has increased its share of marketed production from 18% in 1954 to 51% in 1976. This group accounted for 21% and 32% of the total fertilizer use in 1963 and 1976 respectively. However, the average fertilizer application in the small farms in 1976 was only about 5 kg ha of nutrients (N and P_2O_5) in comparison to 70 kg/ha of nutrients in the large farms. Hence from the pattern of overall resource usages, it is also necessary to differentiate between the supply response of these two types of farm.

1.2. *Previous studies on Kenyan farmers' response*

Though there are a large number of studies on the African farmers' decision behaviour in the context of the allocation of their scarce resources, attitudes towards risk and acreage and output response with respect to price, only a few of them have dealt with Kenyan agriculture in particular. For a detailed review of some of these studies, readers may refer to Alibaruho (1974). Here, we only discuss briefly some literature available on the Kenyan agriculture.

Maitha (1974) studied maize and wheat production response with respect to price. His study used the data on large farms for the period 1954–1969. He adopted the traditional Nerlovian model, in estimating the acreage of wheat and maize separately, with the difference that farmers' price expectation was specified as a distributed lag model with a known lag. Wheat and maize were treated as mutually competing crops. However, he used ordinary least squares in estimating the final reduced form, where acreage under the crop in the previous year, a lagged dependent variable, appeared as an explanatory variable. Also, the

Table 1. *Small farm and large farm acreage under principal crops, 1963 and 1975*

Crop	Large farms '000 ha		Small farms '000 ha	
	1963	1975	1963	1975
Maize	45	68	955	1391
Wheat	113	90	1	21
Rice	–	–	2	6
Sorghum/Millet	1	1	353	281
Barley	18	26	na	na
Pulses	1	2	615	690
Roots	1	1	113	231
Sugar-cane	18	32	5	62
Coffee	31	28	49	73
Tea	18	26	4	37
Sisal	109	74	–	–
Pyrethrum	12	4	8	33
Cotton	–	–	58	68

possibility for autocorrelation was not checked. Maitha's parameter estimates should be considered in the context of these limitations, especially with a small sample. These results indicated that Kenyan farmers do respond to price changes, and that, in general, the price elasticity is higher for maize compared with wheat.

Maitha's (1974) study on coffee in the Kenyan economy, involved setting up a CES production function and assuming that coffee farmers behave rationally: the marginal product of acreage was equated to the rental of land. This resulted in a demand equation for land as a function of expected output and ratio of expected land rental to expected output price. While the expected output was specified as being merely the last year's output, the latter ratio was specified according to a Fisher lag scheme. Maitha estimated the demand equation for land for the coffee industry as a whole, and for large and small farms separately. The price effect was found to be significant for all three groups. However, apart from not checking for autocorrelation etc., the inclusion of an expected output variable in the regression is rather unsatisfactory. Ford (1978) commented rightly, that when the acreage functions are taken together with their yield levels, a simultaneous equations model might be necessary to derive the appropriate long-run elasticities.

Wolgin (1973) adopted a completely different approach in providing useful insights regarding farmers' decisions in allocating various inputs to different crops in an environment of risk. The objective function in his model was to maximise farmers' expected utility rather than income, subject to production and resource constraints. Based on cross-sectional and time-series data he empirically concluded that Kenyan farmers are willing to grow high-risk crops only if they get a higher payoff in expected return.

Etherington's (1973) study on smallholder tea considered a multi-period production function where the age distribution of the stock of trees and changes in technology were explicitly considered. Unfortunately, no price variable figured in this study, and, consequently, a clear acreage and production response to price variables could not emerge. This study, therefore, is unsuitable for looking at the effects of price policies.

It may be noted that much of the above literature on Kenyan agricultural response is outdated, as its data base ended with the time period just after Kenya's independence, in 1963. Wolgin's study was based on cross-section data for the 1968/69 Small Farm Survey, and hence many impacts due to the structural changes since independence were not reflected. Besides, many of the past studies were limited to certain specific crops and only one of the farm types: large or small.

2. The model, data sources and estimation procedure

2.1. *Model*

The traditional Nerlove model, originally formulated for a study on the dynamics of supply in U.S. agriculture (Nerlove, 1958) is as follows:

$$A_t^* = a_0 + a_1 P_t^* + U_t \tag{1}$$

$$P_t^* = \beta P_{t-1} + (1-\beta)P_{t-1}^*, \qquad 0<\beta\leq 1 \tag{2}$$

$$A_t = (1-\gamma)A_{t-1} + \gamma A_t^*, \qquad 0<\gamma\leq 1 \tag{3}$$

where

*	refers to desired or expected long-run equilibrium values
t	refers to time period
A_t and P_t	refer to the acreage and the price of the crop, respectively
β and γ	refer to price expectation and acreage adjustment coefficients, respectively.

The interpretation of the Nerlove model equations and the associated estimation problems have been much discussed in the literature, (see Nerlove, 1958; Askari and Cummings, 1976; Narayana and Parikh, 1981), and a repetition is avoided here.

One of the merits of the Nerlovian framework is that its underlying assumptions allow a straight-forward application of the model to be made, even in relation to developing economies. However, Narayana and Parikh (henceforth

N-P) (1981) experienced some problems when they applied the Nerlove model in order to study farmers' acreage response in India. In their cropwise study, such an application was reported to have resulted in β, the price expectation coefficient, being always equal to one for all crops. N-P argued that accepting these estimates would have meant that farmers in India have only 'naive expectations'.

It may be noted that N-P (1981) considered revenue, instead of price, as an index for profit, because in a dynamic framework, changes in yield levels also affect profits. However, according to them, even when price alone was taken to be an index for profit the results were similar.

N-P then modified the formulation of the revenue (or price) expectation equation as an Auto Regressive Integrated Moving Averages model (ARIMA)[2], and showed that Nerlove's formulation is only a special case of an expectation equation formulated as an ARIMA model. Following N-P (1981), we adopt revenue (or price or yield) expectation equations postulated as ARIMA models. Our model appears as follows:

Desired or long-run equilibrium acreage:

$$A^*_{jt} = a_{0j} + a_{1j} \cdot \Pi^*_{jt} + a_{2j} R_{jt} + a_{3j} Z_{jt} + U_{jt} \tag{4}$$

Revenue expectation:[3]

$$\Pi^*_{jt} = \Pi_{jt} - w_{jt} = \Phi_{1j} \Pi_{jt-1} + \Phi_{2j} \Pi_{jt-2} \ldots . + \mu_j + \nu_{1j} w_{jt-1} + \nu_{2j} w_{jt-2} + \ldots . \tag{5}$$

Stock adjustment:

$$A_{jt} = (1 - \gamma_j) A_{jt-1} + \gamma_j A^*_{jt} \qquad 0 < \gamma_j \leq 1. \tag{6}$$

where:

j	refers to crop j and t refers to time period
$*$	refers to desired, or expected, or long-run equilibrium value
A_{jt}	refers to gross area of crop j in period t
Π_{jt}	refers to revenue (price times yield per hectare) per hectare of crop j
R_{jt}	refers to rainfall for the crop j in period t
Z_{jt}	refers to any other explanatory variable specific to crop j
w_{jt}	is the white noise in the expectation equation
γ_j	is the stock adjustment parameter
U_{jt}	is the random disturbance.

From equations (4) to (6), a reduced form can be written as follows:

Reduced form:

$$A_{jt} = a_{0j} \gamma_j + (1 - \gamma_j) A_{jt-1} + a_{1j} \gamma_j \Pi^*_{jt} + a_{2j} \gamma_j R_{jt} + a_{3j} \gamma_j Z_{jt} + \gamma_j U_{jt} \tag{7}$$

2.2. *Data sources*

Though Kenya has, in comparison to most other countries in tropical Africa, a large data base on area, price and production, for both small and large farms separately, unfortunately, not all these data are available in a neatly compiled form from a single source. Our first task was to compile time-series data, from various published and unpublished sources, namely, the Central Bureau of Statistics, Ministry of Agriculture, Ministry of Economic Planning, various Commodity Boards, FAO, etc. (See Appendix Table 1).

In estimating the acreage response models for the small and large farms, substitutability between crops competing for the same land has to be taken into account. Such substitution patterns vary from district to district and province to province in Kenya due to ecological, agro-climatic and social conditions. However, as the present study is an aggregate study at the national level, an overall substitution pattern at the national level had to be arrived at. This pattern, in the context of the present study, was formulated separately for both small and large farms, by taking into consideration the nature of the soil, the sowing and harvesting seasons of the various crops grown in different districts/provinces of Kenya, and the importance of these districts/provinces with regard to each crop at the national level. Full details of the data base and the formulated crop substitution and crop competition patterns for small and large farmers is given in Narayana and Shah (1982).

Also, one point must be mentioned here regarding the acreage under the two types of farms. There were instances in the past where some of the large farms were purchased by the Government and Cooperatives. Such purchased farms were either subdivided into small farms or used in urban (Nairobi, Thika, etc.) development programmes. This process would show automatically a decrease in the large farms acreage data and an increase in the small farms acreage data. In the present paper, this aspect was not explicitly considered because the available data on such purchases and the type of subdivisions and/or usage are not available, or are not reliable. Nonetheless, the overall situation (see Table 2) seems to suggest that such shifts did not significantly affect the acreage under the two farm types.

2.3. *Estimation procedure*

The exercise was divided into two steps. As a first step, the revenue (or price or yield) expectation equations (5) were estimated first for each crop, and the expected values were computed. In the second step, these expected values, along with other explanatory variables, were used in estimating the reduced form of the acreage response model for each crop; i.e. equations (7).

Table 2. *Large farm-holdings: Kenya 1961-1976. (1963 = 100)*

Year	Index of No. of large farm-holdings (1963 = 100)	Index of large farms. Total area including pastures, fallow land etc. (1963 = 100)	Index of large farms. Area under temporary and permanent crops (1963 = 100)
1961	99	106	107
1962	98	105	104
1963	100	100	100
1964	81	93	94
1965	84	93	112
1966	83	89	101
1967	82	91	105
1968	81	90	100
1969	83	90	101
1970	86	91	101
1971	86	91	98
1972	86	91	98
1973	86	90	96
1974	88	90	101
1975	89	90	103
1976	89	90	109

2.3.1. *Expectation equations*

In general an ARIMA (p, d, q) process is written as:[4]

$$\Phi(B)\,\Delta^d\,Y_t = \mu + \nu(B)\,w_t \tag{8}$$

where

B = the backward-shift operator, i.e. $B^n Y_t = Y_{t-n}$,
Δ = the differencing operator, i.e. $\Delta Y_t = Y_t - Y_{t-1}$, and $\Delta^2 Y_t = \Delta(\Delta Y_t) = \Delta Y_t - \Delta Y_{t-1}$ and so on,
$\Phi(B) = 1 - \Phi_1 B - \Phi_2 B^2 - \Phi_3 B^3 \ldots - \Phi_p B^p$, i.e. p is the order of auto-regressive process,
$\nu(B) = 1 - \nu_1 B - \nu_2 B^2 - \nu_3 B^3 \ldots - \nu_q B^q$, i.e. q is the order of moving average process,
d = the degree of differencing applied to the original time series Y_t to reduce it into a stationary series (note that $\Delta^d = (1 - B)^d$).
μ = a constant determining the level of the time series
Φ_i, ν_i = parameters, and
w_t = white noise.

For each crop, an appropriate ARIMA scheme constituting p, q, d, has been identified and selected which satisfied a diagnostic checking consisting of[4]

(a) Stationarity conditions of the estimated series implying certain restrictions on the values of parameter estimates and also

(b) a χ^2 (Chi-square) test based on the residual autocorrelations.

The selected schemes for revenue, price and yield for all large and small farm crops are shown in Table 3.

Table 3. *Large and small farms[a]: Selected Box-Jenkins ARIMA process schemes (pqd) for crop price, yield and revenue*

	Selected ARIMA process schemes (pqd)[b]				
	All[c] farms	Large farms		Small farms	
	price	Yield	Revenue	Yield	Revenue
Maize	210	120	121	120	110
Wheat	111	110	111	121	110
Rice	111			110	101
Sorghum/Millet	151			110	200
Barley	101	211	201		
Pulses	151			200	201
Roots	101			100	101
Sugar-cane	200	100	101	110	120
Tea[d]	120	110	101	110	120
Sisal	210	200	100		
Pyrethrum	210	120	110	120	200
Cotton	200			120	110

[a] Number of observations, i.e. length of time series for each crop are given in Table A1.
[b] See Section 2.3.1. for definition of p, q and d.
[c] Large and small farms face the same price (see Note 5).
[d] Tea ARIMA scheme for export price 211.

Note that the price expectation equations are the same for both large and small farms. This is because both these farm types would face the same prices, and any differences in their revenues per hectare of crop j are a result of the differences in their yields.[5]

One interesting feature observed during this part of the study was that the finally-identified ARIMA schemes, which for most of the crops showed a reasonable value of p, q and d (i.e. p and $q \leq 2$ and $d \leq 1$), gave a large value of q (i.e. number of moving average terms) when applied to the prices of pulses and coarse grains.

2.3.2. *Acreage response equations*

When estimating the acreage response equations, two important points have to be noted: (a) our data are time series, and the possibility of autocorrelation exists; (b) the reduced form equation (7) has a lagged dependent variable on the right-hand side. In the case of ordinary least squares (OLS), the former problem leads to underestimated variances of the estimated parameters (hence, overestimated *t*-coefficients); the latter problem leads to biased estimates in small samples, though they are consistent in the large samples; and a combination of autocorrelation and the presence of a lagged dependent variable, does not even lead to consistent estimates.[6] However, the presence on the right-hand side of a number of explanatory variables other than the lagged dependent variable helps to reduce the asymptotic biases of the estimates in such cases.[7] While the final specifications in our acreage response equations involve a number of other such variables, we decided to allow for autocorrelation. We assumed a first order autocorrelation. The search procedure of Hildreth and Lu was followed because (a) the Cochrane-Orcutt procedure is likely to give only a locally stationary estimate of the autocorrelation parameter, (b) Durbin's procedure has been reported in the econometric literature to perform less satisfactorily than the Hildreth-Lu procedure in estimating the true autocorrelation parameters[8] and (c) depending on how large the sample size is, the Hildreth-Lu procedure would give very close estimates to those obtained from the maximum likelihood procedure. Equation (7) was estimated for 40 values of the autocorrelation parameter for each crop over a range of -1.00 to $+1.00$ with a step-size of 0.05, and the parameters corresponding to the highest $\bar{R}^2$ were selected. The Durbin-Watson statistics reported in Table 4 are at these parameter estimates. The Durbin's '*h*' statistic is not calculated separately, because if the autocorrelation was not present, the Hildreth-Lu procedure would reveal that phenomenon anyway.[9]

Equation (7) was estimated for each crop separately, for both small and large farms. We did not adopt the approach of a simultaneous equations system because the specification of the explanatory variables varied from crop to crop, and also between the two types of farm. Besides, even for an inter-farm level or inter-cropped systems, any cross-equations-correlation of the type of Zellner's seemingly unrelated equations system will not be significant, given that large farms and small farms are geographically, as well as agro-climatically, wide apart. Hence equation (7) was estimated on a single equation basis with tailor-made specifications in each case reflecting the particular conditions.[10] While discussing the results, these conditions will be briefly spelt out.

Note that the expectation equation (5) was estimated for each crop using the actual variable (revenue or price or yield) as the dependent variable. One may argue that actual price, for example, might depend on acreage just as the acreage might depend on the price, and hence acreage response is implicitly included in the expectation equation itself, leading to simultaneity between price and acreage. But, agriculture is highly characterised by production-lags, and the actual price is determined only during market-exchange where predetermined agricultural supplies are traded. Hence, it is justifiable only to assume a chain-dependence as follows: (a) past actual prices and disturbances determine the current year's expected prices, (b) the current year's expected prices determine the current year's acreage, and (c) the current year's acreage and production determine the current year's actual prices, which in turn, determine next year's expectations, and so on. This chain is not violated while estimating expectation equation (5) even though the dependent variable there is the actual price; that formulation only receives the estimates of the expected prices and random disturbances endogenously. In view of this, the argument of simultaneity does not apply, and hence our two-step procedure is justifiable.

One important admission: In our first attempt, both expected price and expected yield were introduced as explanatory variables[11] in each equation, for both large and small farms. The price variable is important for catching the economic response; its estimated coefficient multiplied by the ratio of price to acreage indicates the short-run price elasticity of supply which, if divided by the stock adjustment parameter, indicates the long-run price elasticity. The yield variable explains the effect of technological development through changes in levels of application of farm inputs such as fertilizers, high-yielding variety seeds, etc. Quite often, only one of these variables was found to be significant, and the other irrelevant variable (i.e. if the absolute value of its *t*-coefficient was less than one) was dropped from the regression. The significance levels shown in Table 4 are subject to this limitation. However, it may be noted that there is not yet a theoretically well-established and clear procedure to judge the significance of the *t*-values in such cases.[12]

3. Estimation results

A summary of the estimation results of acreage responses of large and small farms are presented in Table 4. Before discussing these results, the following should be noted with respect to the coefficient of the A_{jt-1} variable in equation (7), i.e. $1-\gamma_j$:

(a) If $(1-\gamma_j)$ is significantly different from zero, then γ_j is significantly different from one.

(b) If $(1-\gamma_j)$ is not significantly different from zero, then γ_j is not significantly different from one.

Thus the *t*-coefficient of $(1-\gamma_j)$ would only reveal whether γ_j is significantly different from one or not. To find out whether γ_j is significantly different from zero or not (in spite of $0 < \gamma_j!$), one should test whether $(1-\gamma_j)$ is significantly different from one or not. This would lead to a *t*-statistic such as:

$$t(\hat{\gamma}_j) = -\hat{\gamma}_j / SE(1-\gamma_j) \qquad (9)$$

where $\hat{\gamma}_j$ is (1-coefficient of A_{jt-1} of the estimated equation 7).

Depending on whether the value of $t(\hat{\gamma}_j)$ falls within an appropriate critical region of the t-distribution with given numbers of degrees of freedom, one can test the null hypothesis of $\hat{\gamma}_j$ being equal to zero. The computed values of $\hat{\gamma}$ and $t(\hat{\gamma}_j)$ are shown in Table 4.

3.1. *Large farm results*

The value of the area adjustment parameter ($\hat{\gamma}$) suggests that, for the large farms, the farmers are able to adjust the acreage under sugar towards the desired acreage and to a lesser extent this is also the case for maize, wheat and pyrethrum. For the remaining crops (sisal, tea, barley, and pineapple) the results of the estimation show γ to be statistically different from zero (Section 3, equation 9). For sisal, the inability of farmers to achieve the desired acreage may be due to the large fluctuations in the world market price (producer prices are set in line with world market price by the Kenya Sisal Board). In the case of tea, the result is understandable since tea acreage on the large farms is constrained by the lack of additional land suitable for tea. However, the low value of $\hat{\gamma}$ for barley is somewhat perplexing, since the demand for barley from the breweries for the production of beer is rapidly increasing, and in the past, there was no significant competition from small farms; also, on the large farms, additional land suitable for barley could be made available. Pineapples are produced under irrigation, and the farmer's inability to achieve the desired acreage is possibly due to the limitations of irrigation expansion.

The results of the estimation of the acreage equations suggest that large farmers were generally responsive to the price variable. For maize, wheat, barley, pineapple and tea, the coefficient of the price term was significant at a 5% level, whereas for sugar-cane and sisal, the significance was at a 10% level. Among the cereal crops on the large farms, there is competition between maize, wheat and barley. For these three crops, equations with expected relative prices as well as with expected own prices were estimated. Only acreage response equations with satisfactory[13] variables were chosen, and the results show that for maize, the own-expected price, for wheat the relative-expected wheat-to-maize price, and for barley, the relative-expected barley-to-wheat price, explains the acreage response. The results for sugar-cane – mainly produced in the Nyanza and Coast provinces where maize is an alternative crop – showed that the relative-expected price of sugar-cane-to-maize is relevant. For tea, the expected export price has been used, since a major share of the production is exported (e.g. 92.2% of total production was exported during the period 1961–76) and the Kenya Tea Board sets producer prices in line with export prices. In the case of pineapple, at present: a minor crop (5000 ha fully irrigated) but with a large export potential, the previous year's price rather than the expected producer price was used.

The yield levels for most large farm crops are generally optimal, as high level production technology is often used. Hence further increases in yields could be more difficult. The yield variable was insignificant in the case of all crops except barley, where the relative expected yield of barley-to-wheat turned out to be significant at a 20% level only.

For pyrethrum, the coefficient of the expected revenue term was significant at a 20% level. In this case, large farmers' acreage response is basically explained by the small farmer's share of the total pyrethrum acreage in Kenya; the coefficient of this variable being significant at the 5% level. This result is understandable, since during the last two decades there has been a deliberate government quota policy to make this a small farmer's crop.

Time trends were introduced as variables for barley and sisal. For barley, the time trend (coefficient positive and significant at the 5% level) represents the increasing demand for beer in Kenya; beer production as well as consumption were introduced as alternative explanatory variables for the time trend, but were not significant. For sisal, the time trend (coefficient negative and significant at the 5% level) was introduced to represent an overall declining trend in sisal acreage as a result of some sisal estates being subdivided and the land being sold for housing estates (e.g. Thika) and industrial complexes (e.g. Voi) as well as the instability in the world market price.

Crop-wise time-series data for the rainfall variable for the large farms, derived on the basis of district rainfall station data and crop acreage, were introduced in all the acreage response equations. However, this variable was significant only for wheat, and even then at a 20% level. Supplementary irrigation is often used in the large farms, and hence this result is partly understandable.

Table 4 also shows data on the statistical measures, namely, $\bar{R}^2$, Durbin-Watson statistic and rho – the autocorrelation parameter. In the case of the latter parameter, only sugar-cane has a low value (0.05), i.e. almost no autocorrelation.

3.2. *Small farm results*

For the small farms, the farmers are able to adjust the acreage under maize, sorghum/millet, and pulses towards the desired acreage, and, to a lesser extent, this is also the case for rice, sugar-cane, tea, pyrethrum and cotton. For wheat and roots, the rate of adjustment towards the desired levels is lower. In general, the small farms are able to adjust the acreage under food crops towards the desired acreage much more than in the case of acreage under non-food crops ($\hat{\gamma}$ is generally higher for food crops). This could be in response to the increasing self-consumption on the small farms; more than 70% of Kenya's rapidly growing population is in the small-farm sector.

The results of the acreage response equations show that, unlike the large farms, the small farms are generally much more responsive to the yield variable. This applies especially to food crops, so these are considered first.

The coefficient of the expected yield term was significant at 5% for sorghum/millet, rice, pulses and sugar-cane, and was significant at the 20% level for maize. For wheat, the coefficient of the expected revenue term was significant at the

5% level, and the coefficient of the expected price variable was significant at the 5% level for pulses and roots, and at the 20% level for maize. For pulses, the small farmer's current maize acreage was also used as an explanatory variable to account for the often-practiced method of broadcasting pulses (especially beans) in the maize crop area. The coefficient of this term is significant at the 5% level.

Rice is mainly grown under irrigation in the government financed and operated irrigation schemes, and the time trend represents the rate of expansion of the irrigation schemes. Similarly for wheat, the time-trend variable represents the rate at which 'new' wheat areas (e.g. Narok District) are being opened up by the government for small-holder occupation. Here maize is a possible competing crop, although this point could not be considered, since the present wheat acreage is less than 3% of the maize acreage on the small farms. In the case of roots, the time trend was introduced to represent the rapidly increasing urban (and also rural) demand for white potatoes.

In the 1970s, small holders, especially cooperatives, rapidly increased the acreage under sugar-cane. The production from this sector has enabled Kenya to reach a self-sufficiency and even an export position. For this crop, the price variable was not relevant, and only the yield term explains the acreage response.

Among the non-food crops, government policy on the promotion of tea and pyrethrum for small-holder production has been especially effective and successful. These crops are important in terms of profitability, as well as creating employment opportunities. For tea, the acreage model was formulated in terms of area differences.[14] This specification implies that the acreage adjustment parameter ($\bar{\gamma}$) has to be interpreted in terms of farmers' desires over year to year changes in the level of their acreage under tea. The explanatory variable (the previous year's actual revenue) is significant at the 5% level.

During the 1960s and early 1970s, small farmers became the major producers of pyrethrum. Kenya is a price maker for pyrethrum in the world market and if demand continues to rise (especially if synthetic alternatives are not available, and international environmental concern for synthetic insecticides increases) then small-farm acreage will continue to grow. The results of the estimated equation show that the coefficient of expected revenue is significant at the 5% level.

Cotton, grown by small holders mainly for the domestic textile industry in Kenya, has been a problem crop in two respects. First, the pest and disease infestation compounded with low level of husbandry and shortage of chemical supplies, and, second, the intensive labour requirement for cotton has often conflicted with food crops (especially maize) and has led to the slow growth of cotton production. In the estimated equation, cotton acreage is explained by the previous year's price and the previous year's yield, signficant at the 20% and 5% levels, respectively.

The rainfall variable was not generally significant for most crops except maize and cotton at the 20% level, and 5% for pyrethrum. Most small-holder production in Kenya is under rainfed conditions over a wide range of agro-climatic conditions. In this context, data on the presently used crop-specific rainfall time-series data for small farmers, derived on the basis of district crop acreages and available rainfall station data, needs to be improved (Narayana and Shah, 1982). For pyrethrum, the data are fairly reliable, since this crop has been produced in a few districts where there is a large meteorological station coverage.

Data in Table 4 show that, for all crops, the $\bar{R}^2$ for the estimated equations were high; the lowest values being for cotton and tea. The Durbin-Watson statistics are also satisfactory for all crops. For rice, tea and pyrethrum the autocorrelation parameter, rho, turned out to be almost zero, i.e. there is no autocorrelation for these crops.

4. Policy considerations and conclusions

Most of the large farmers' production is marketed through the official marketing boards. A large proportion of the small farmers' food crops, except wheat, rice and sugar-cane, are produced for self-consumption, and only the surplus is marketed through local markets and to a lesser extent through the official marketing boards. The latter enforce the producer and consumer prices and have a monopoly over all purchases. Wheat, rice, sugar-cane and all the non-food crops are essentially marketed through the official marketing channels.

From the point of view of economic rationality, both types of farmer ultimately react to revenue (or profit) incentive. However, for the large farms, which are already 'technically' advanced in farming, further increases in their yield levels could be difficult. In contrast, for the small farms, which are 'technically' not as advanced, there is a considerable possibility of increasing the yields. This implies that for large farms, increases in revenue would basically come from price changes, whereas for the small farms, increases in revenue would come from both price as well as yield changes. This aspect could be the main reason why yield terms resulted in significant coefficients for the small farms, whereas the price terms resulted in significant coefficients for the large farms. Additionally, for small farms, self consumption is also a much larger part of the output, and hence prices may not be as significant as for large farms.

Table 4 also shows the movement of relative yields for some important crops between 1961 and 1976. While small farms could increase their yield levels relative to large farms, particularly in the case of tea, wheat and pyrethrum, this relative gap widened in the case of maize.

The overall results suggest that a produce price policy alone would be inadequate to influence the small farmers' cropped acreage. In addition, a compatible and integrated policy regarding the provision of input subsidies and credits is necessary to affect the small farmers' crop yields, and hence the cropped acreage. The integration of a simultaneous price and input policy in relation to specific crops is essential to ensure the desired supply. In the past, policymakers in Kenya have tended to concentrate on producer price policies, especially for basic food

Table 4. *Estimation results of acreage response for large and small farms*

	$\hat{\gamma}$[a]	$t(\hat{\gamma})$	Expected revenue	Expected price	Expected yield	Time trend	Rain-rall	Other variable	$\bar{R}^2$	D.W.	Rho	Relative yields Large/Small farms 1961	Relative yields Large/Small farms 1976
Large farms													
Maize	0.54	-3.17		*					.59	1.45	0.45		
Wheat	0.55	-3.20		*[c]			***		.76	1.33	0.95		
Barley	0.17	-0.79		*[d]	***[d]				.82	1.60	0.60		
Sugar-cane	0.94	-2.81		**[e]		*			.88	1.85	-0.05		
Pineapples	0.02	-0.13		*[f]					.90	2.18	-0.50		
Tea	0.01	-0.62		*[g]					.98	2.42	-0.52		
Pyrethrum	0.60	-3.38	***					*[h]	.90	1.07	0.60		
Sisal	0.30	-3.45		**		*			.80	1.81	-0.45		
Small farms													
Maize	0.82	-1.44		***	***		***		.86	2.18	-0.30	1.17	2.00
Wheat	0.30	-1.62	*			*			.99	2.36	-0.50	2.63	1.67
Sorghum/Millet	0.75	-4.15			*				.75	1.71	0.70		
Rice	0.57	-3.28			*	*			.98	1.37	-0.05		
Pulses	0.73	3.29		*	*			*[i]	.93	2.01	-0.35		
Roots	0.10	1.36		*		*			.98	2.09	-0.20		
Sugar-cane	0.51	-1.95			*				.76	1.63	0.15	1.28	1.01
Tea[b]	0.51	-2.84	*[j]						.68	1.99	0.04	6.57	3.44
Pyrethrum	0.56	-3.38	*				*		.80	2.29	0.00	1.55	1.35
Cotton	0.58	-3.40		***[k]	*[k]		***		.63	2.00	-0.65		

Notes

*, **, ***	significant at a 5%, 10% and 20% level respectively
a	The estimated coefficient $(1 - \gamma)$ of A_{jt-1} in equation 7 was found to be significant at a 5% level for all large farm crops except for sugar-cane where the coefficient is insignificant. For small farms this coefficient was found to be significant at 5% for wheat, rice, roots, tea, pyrethrum and cotton, at a 20% level for sorghum/millet, pulses and sugar-cane and insignificant for maize.
b	For tea (small farms) $\hat{\gamma}$ is 1 — (coefficient of δA_{jt-1} of the estimated equation, see Note 14).
D.W.	Durbin-Watson Statistics
Rho	Value of ρ in $U_t = \rho U_{t-1} + e_t$
$\hat{\gamma}$	1 — (coefficient of A_{jt-1} of the estimated equation 7)
$t(\hat{\gamma})$	as defined in equation 9
c	Ratio of expected wheat/expected maize price
d	Ratio of expected barley/expected wheat price and similarly for yield
e	Ratio of expected sugar/expected maize price
f	Actual price lagged 1 year
g	Expected export price
h	Small farms share of national pyrethrum acreage lagged one year
i	Small farm current maize area
j	Actual revenue lagged one year
k	Actual price and yield lagged one year

commodities. This raises one important issue, namely, are the present price policies 'reasonable'. This is not an irrelevant question to ask especially when the data, though somewhat scanty as they are, suggest that Kenya exported cereals (maize in particular) in the year when per capita availability domestically was as low as 277 gms per day, in the year 1968, and imported in the year when the domestic availability was as relatively high as 453 gms per day, in the year 1971. It may seem at the outset, that availability was low because of exports and high because of imports. However, a deeper understanding suggests that apart from the policy regarding producer price, consumer price and trade, a whole lot of issues relating to institutional structure seem to dictate the pace of Kenyan agricultural development. These aspects are discussed in detail elsewhere, see Narayana and Shah (1984c).

APPENDIX

Table A1. Data sources

Crop	Time-series period	Source
L.F. Wheat	1957–68	Economic Review of Agriculture, 1963, 1968
L.F. Wheat	1969–76	National Wheat Board
S.F. Wheat	1961–76	National Wheat Board, Economic Reviews of Agriculture 1969–76, Economic Surveys 1974–76
L.F. Maize	1954–67	Economic Review of Agriculture 1963, 1968
L.F. Maize	1968–76	Maize and Produced Board, Food & Marketing Project
S.F. Maize	1961–76	FAO data, Maize and Produce Board, Surveys (1968/9, 1974–77) of small farms, Economic Reviews of Agriculture 1969–76
L.F. Tea	1954–68	Economic Review of Agriculture 1963, 1968
S.F. Tea	1959–68	Economic Review of Agriculture 1963, 1968
S.F. and L.F. Tea	1969–76	Economic Reviews of Agriculture 1969–76 Economic Surveys 1968–76, and Kenya Tea Board
S.F. Rice	1961–76	National Cereals and Produce Board, Kenya Statistical Abstracts 1968–76
L.F. Sisal	1954–76	Kenya Sisal Board, Economic Reviews of Agriculture, 1963, 1968, 1969–76, Kenya Statistical Abstracts 1968–76
S.F. & L.F. Pyrethrum	1958–76	Kenya Pyrethrum Board, Economic Reviews of Agriculture 1963, 1968, 1969–76
L.F. Barley	1957–76	Kenya Breweries, Economic Reviews of Agriculture 1963, 1968, 1969–76, and FAO
S.F. Cotton	1961–76	Cotton Lint and Seed Marketing Board, Economic Reviews of Agriculture 1963, 1968, 1969–76
S.F. Pulses	1961–76	FAO, National Cereals and Produce Board, 1968–69 and 1974–77 Survey of Small Farms, Food & Marketing Project
S.F. and L.F. Sugar	1961–76	Economic Reviews of Agriculture 1968, 1969–76 and Economic Surveys 1968–76
S.F. Roots	1961–76	FAO and 1968/9, 1974–77 Surveys of Small Farms
S.F. Sorghum/Millet	1961–76	FAO and 1968/9, 1974–77 Surveys of Small Farms Economic Reviews of Agriculture 1969–76
L.F. Pineapples	1958–76	Economic Review of Agriculture, 1963, 1968 Horticulture Development Study, Ministry of Agriculture

L.F. Large farms
S.F. Small farms

Note

1. Large farm data on crop acreage: Agricultural Census of Large Farms 1962–76.
2. Price information from Kenya Statistical Abstracts 1961–76, various commodity Boards as mentioned above and FAO.

NOTES

1. A detailed study of the coffee sector in Kenya with a two-stage least square estimation model for large and small farms acreage response is reported in Shah and Narayana (1984b).
2. See Box and Jenkins (1970) and Nerlove (1971).
3. For some crops, the equivalent expected producer price (P^*_{jt}) and/or the expected yield (Y^*_{jt}) instead of the expected revenue (Π^*_{jt}).

4. See Box and Jenkins (1970) or Pindyck and Rubinfeld (1976).
5. Unfortunately, the mathematics of the estimation procedure forces us to assume that price expectations by both the farms is the same. One could argue both ways, for and against this assumption!
6. See Johnston (1972).
7. See Malinvaud (1970).
8. See Maddala (1977).
9. Given an equation such as $Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \beta_3 x_t + U_t$ the Durbin's '*h*' statistic can be computed as follows:

$$h = r\sqrt{n}/[1 - \hat{v}(\beta_1)]\,;$$

with r being approximately equal to $[1 - \frac{1}{2}$ (Durbin-Watson statistic)$]$, n = number of observations and $\hat{v}(\beta_1)$ = the OLS estimate of the variance of $\hat{\beta}$ (i.e. with autocorrelation parameter being zero). '*h*' is a standard normal variate, which can be used to test the null hypothesis of zero autocorrelation.

10. In a different context, Krishna (1982) argues for studying aggregate supply responses.
11. Only when the correlation between these two variables was low enough so that multicollinearity did not arise. Whenever that was not the case, a composite revenue term (price times yield) was used.
12. See Maddala (1977).
13. The parameter estimate is considered to be 'satisfactory' if the estimate is of expected sign and *t*-coefficients are significant.
14. Estimation in the undifferenced form showed unsatisfactory parameter estimates involving incorrect signs and an out-of-bound value of γ, indicating essentially multicollinearity. Hence for tea (small farms) the model was estimated in the following form:

$$\text{ardf}_t = \alpha_1\, \text{ardf}_{t-1} + \alpha_2\, \text{revn}_{t-1} + \text{c}$$

where

$\text{ardf}_t = \text{area}_t - \text{area}_{t-1}$

$\text{ardf}_{t-1} = \text{area}_{t-1} - \text{area}_{t-2}$

revn_{t-1} = revenue at $(t-1)$

and α_1 and α_2 are the estimated coefficients.

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N. S. S. Narayana and M. M. Shah
International Institute for Applied Systems Analysis
A-2361
Laxenburg
Austria