ELSEVIER

Agricultural Economics 14 (1996) 21-31

AGRICULTURAL ECONOMICS

Expectations, supply response, and marketing boards: An example from Kenya

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Accepted 4 December 1995

Abstract

Whether farmers form price expectations adaptively or in a forward-looking manner has implications for supply response analysis and for the implementation of agricultural policy reform. This paper examines the formation of price expectations by Kenyan export-crop farmers who market their produce through a monopsonistic parastatal. The analysis allows for relaxation of the small-country assumption within a rational expectations framework. Production behavior is consistent with expectations of future prices based on indicators of aggregate supply and of the marketing board's purchasing capacity. The finding that price forecasts may be formed using information other than previous price levels implies that marketing reforms that raise prices may not raise the relevant price expectations. To elicit a positive supply response, market reforms should be sensitive to farmers' interpretation of institutional signals as well as previous prices.

1. Introduction

Analyses of African agriculture commonly assume price forecasts are based solely on past prices. [1] If farmers base their forecasts on past prices alone, any reforms to raise prices would raise expected prices. However, if farmers use other indicators of market conditions to make forecasts, reforms that raise current prices may not raise expected prices and could undermine the accuracy of forecasts by altering the meaning of the indicators. Greater uncertainty about future prices will tend to reduce the incentives for risk averse farmers to enter the market and dampen the supply response to price increases. The formation of expectations, as well as physical constraints on production, may help explain why structural adjustment programs in Africa have had only limited impact on the agricultural sector, despite gains in other areas (World Bank, 1994, table A20).

Price expectations may be influenced by institutional or situational factors aside from previous prices. African farmers who have long faced monopsonistic parastatals may use information about the current state of those institutions when forecasting prices. If indicators relating to the marketing institutions themselves influence price expectations, marketing reform must consider how farmers interpret the actions of these institutions as well as the price levels. The impact of different types of information on supply behavior can be examined through tests of the rational expectations hypothesis (Muth, 1961).

For specific crops, supply response analysis may

[1] Surveys in Ogdu and Gbetibouo (1990) and in Bond (1983) reveal uniform use of adaptive models. An exception to this trend appears in Saad and Simpson (1991).

SSDI 0169-5150(95)01176-5

be complicated by the failure of the small-country assumption. As African countries attempt to develop new markets for specialty exports, there is a growing potential for price to be endogenous at the national or regional level, while remaining exogenous for individual producers. The next section presents a model for testing the rational expectations hypothesis when aggregate production in specific regions can affect the price level. The paper then shows that the behavior of Kenyan pyrethrum farmers reflects price forecasts based on known conditions in the marketing institution and other indicators of future market conditions. Because farmers' understanding of the marketing institutions may affect price forecasts, agricultural revitalization may require not only market reforms to improve producer prices, but also transparent implementation of those reforms.

2. Theoretical model

Agricultural supply response in developing countries is often examined using the adaptive expectations model of Nerlove (1958), in which the expected price (P_t^e) is a function of the most recent past price (P_{t-1}) and past errors in predicting prices. Formally:

$$P_t^e = P_{t-1} + \gamma(P_{t-1} - P_{t-1}^e) \tag{1}$$

In estimations, this model is usually represented as a distributed lag of past prices. Detailed discussion of the adaptive expectations model and extensions to it are found in Askari and Cummings (1976), and Colman (1983). While this formulation is widely used, it is also widely criticized because it does not allow information about the causes of price movements or the probability of a future price shock to influence estimates of future prices (Tada, 1991).

Models in the tradition of the rational expectations approach (Muth, 1961) allow all available information relating to future market conditions to be used when forecasting prices. Growers facing a monopsonistic parastatal may be aware of changes in inventories, in the financial status of the marketing intermediary, or in other factors that could influence prices. In Kenya, for example, parastatals are required to provide annual reports to the growers covering this information and the news media report on major developments in these variables. A forward-looking farmer may consider the factors affecting prices in a manner analogous to an inverse demand function that sets the market clearing price at the projected time of sale (P_t) as a function of quantity (Q_t), the price of substitutes (PS_t), and other exogenous factors (Y_t) such as income or population:

$$P_t = f(Q_t, PS_t, Y_t) \tag{2}$$

The expected price is simply the expected value of Eq. (2). Imposing a linear form, this implies the following system of demand and supply equations:

$$P_t = a + bQ_t + cPS_t + dY_t + u_t \tag{3}$$

$$Q_t = g + hE(P_t | I_{t-1}) + kZ_t + \epsilon_t \tag{4}$$

where Z_t represents exogenous variables affecting supply and $E(P_t|I_{t-1})$ is the expectation of Eq. (3) given information available at period $t-1$, the time of planting. If information gathered after planting time could affect supply, $E(P_t|I_t)$ would be the appropriate expected price. Expected prices could still diverge from actual prices if P_t were not paid until period $t+1$, as is the case in the application to follow.

Substituting Eq. (4) into Eq. (3), taking the expectations, and substituting the expected price term back into Eq. (4) implies:

$$Q_t = g + \frac{h(a+bg)}{1-bh} + \frac{hbk}{1-bh}\tilde{Z}_t + \frac{hc}{1-bh}\widetilde{PS}_t + \frac{hd}{1-bh}\tilde{Y}_t + kZ_t + \epsilon_t \tag{5}$$

where the tildes indicate expected values formed in the previous period. Eq. (3) and Eq. (5) can be represented in reduced form by the following system for estimation

$$P_t = \alpha_0 + \alpha_1 Q_t + \alpha_2 PS_t + \alpha_3 Y_t + u_t \tag{6}$$

$$Q_t = \beta_0 + \beta_1 \tilde{Z}_t + \beta_2 \widetilde{PS}_t + \beta_3 \tilde{Y}_t + \beta_4 Z_t + \epsilon_t \tag{7}$$

If expectations are formed as the model suggests, the terms reflecting expected price in Eq. (7) must be consistent with the inverse demand function, Eq. (6). This implies the restriction that:

$$\beta_2 = \beta_3 \frac{\alpha_2}{\alpha_3} \tag{8}$$

The significance of cross-equation restrictions such as Eq. (8) has been used as a test of the rational expectations hypothesis (Hoffman and Schmidt, 1981; Shonkwiler, 1982; Goodwin and Sheffrin, 1982; Antonovitz and Green, 1990). If the restricted model differs significantly from the unrestricted form, either the expectation is formed in some other manner or the model is misspecified. If the restrictions hold, the rational expectations hypothesis is supported. Comparison of the performance of alternative expectations models has been inconclusive in developed countries (McIntosh and Shumway, 1994) and remains unattempted in developing countries. While the above test cannot prove that farmers form expectations as the model dictates, support of the rational expectations hypothesis would suggest the need to consider the potential impacts of altering the significance of data in the model without informing farmers. For example, institutional reforms could alter the relationship between an exogenous variable in demand and the producer price, thereby influencing the effectiveness of the price forecasts.

If the small-country assumption does not hold, producers will recognize that their aggregate behavior influences price. In many cases, exogenous factors influencing production vary within the nation, making aggregate regional production a factor driving price movements. Disaggreggation of Eq. (7) by production region allows incorporation of differing exogenous conditions and sensitivity to the possibility for supply in any one region to influence price nationally. In a dissagregated model, production in each region could affect price expectations in every other region while being influenced by factors unique to that region. Because production in each region influences the expected price nationally, supply response in individual regions should be distinct, but dependent on conditions in the other regions. This suggests replacement of Eq. (4) and Eq. (7) with:

$$Q_{t,i} = g_i + h_i E(P_t | I_{t-1}) + k_i Z_{t,i} + \epsilon_{t,i} \quad (9)$$

$$Q_{t,i} = \beta_{0,i} + \sum_{j=1}^{n} \beta_{j,i} \tilde{Z}_{t,j} + \beta_{n+1,i} \widetilde{PS}_t + \beta_{n+2,i} \tilde{Y}_t + \beta_{n+3,i} Z_{t,i} + \epsilon_{t,i},$$

$$Q_t = \sum_{i=1}^{n} Q_{t,i} \quad (10)$$

where i and j designate the districts 1 through n. This implies a system of n reduced form supply equations, a demand equation like Eq. (6), and n cross equation restrictions for estimation. Because of contemporaneous correlation and the nonlinearity of the restrictions, the model must be estimated in a system of seemingly unrelated regressions using nonlinear methods. The next section applies such a model to Kenyan pyrethrum.

3. Pyrethrum

Pyrethrum (*Tanacetum cinerariaefolium*), a daisy-like flower containing an insecticidal chemical compound (pyrethrins), is Kenya's third or fourth largest export crop by value. The crop's requirements of consistent sunlight hours, regular chilling, and steady rainfall make it well-suited to the Kenyan highlands, where about 70 percent of global trade originates. Within Kenya, two-thirds of national production is grown in two districts, Kisii and Nakuru (Table 1). The plant is grown almost exclusively by small-scale farmers using substantial household labor, but negligible amounts of purchased inputs. [2] The dried flowers are sold to the Pyrethrum Board of Kenya (PBK) which processes the flowers and exports their extract. Because processing is capital intensive and there appears to be excess capacity, some public enterprise is likely to remain the primary marketing intermediary for Kenyan growers. Particularities in the management of that marketing institution determine the information farmers may use to forecast prices, but such managerial practices may change rapidly during structural adjustment programs.

Under Kenya's Pyrethrum Act of 1978, the pyrethrum board is obliged to remit all annual profits to the growers (Republic of Kenya, 1978). While the board appears to fulfill its legislated requirements (Grosh, 1986), the marketing system does not offer

[2] More detailed discussion of the cultivation of pyrethrum flowers can be found in Nelson (1975) and Wanjala and Odhiambo (1986). Argwings-Kodhek (1996) and Winter-Nelson (1996) include detailed descriptions of the agricultural economy of Kenya's primary pyrethrum growing regions.

Table 1
Pyrethrum production (MT dried flower)

Year	Global	Kenya	Kisii	Nakuru
1968	19375.9	11237.0	2955.3	1019.0
1969	15093.5	7423.0	3065.7	643.7
1970	10967.9	6005.0	2377.7	636.1
1971	15210.4	9748.0	5859.8	880.5
1972	21334.5	14414.0	8555.6	1344.8
1973	17606.5	10698.0	5576.9	1266.6
1974	19645.2	13722.0	8055.1	1543.5
1975	22827.3	15035.0	9586.7	1345.8
1976	21008.6	14267.0	8916.7	1487.4
1977	16918.6	11429.0	6529.2	1712.6
1978	12806.0	8441.0	4138.8	1614.2
1979	11068.0	7950.0	3360.9	2039.6
1980	13527.0	10424.0	5028.9	2581.5
1981	19341.0	15704.0	7582.0	3940.8
1982	22257.0	18720.0	6892.9	5656.7
1983	12352.0	8974.0	2407.6	2914.1
1984	5771.0	3156.0	609.7	1079.9
1985	6099.0	3101.0	734.5	1096.3
1986	5836.6	3117.0	915.8	1184.5
1987	8942.0	6407.0	1312.9	2842.5
1988	9121.1	6689.0	1196.0	3292.2
1989	10163.0	7538.2	1283.6	3610.2
1990	11637.5	8987.5	1802.9	4256.2

Sources: Production in Kenya is based on Pyrethrum Board of Kenya, Crop Production Files; District Annual Report: Kisii, various years; District Annual Report: Nakuru, various years. Global production based on United States Department of Agriculture, various years; the statistical abstracts of Zaire, Rwanda, Tanzania, Ecuador, and Papua New Guinea; and the commodity files of the Natural Resources Institute (UK).

Table 2
Timing of information flows to producers

Period	Prices known	Other information
Period t		
Planting season	IP_t, P_{t-1}	S_t, $QF_{t,i}$, PC_{t-1}
Growing/harvest season	IP_t, P_{t-1}	S_t, $QF_{t,i}$, PC_{t-1}
Period $t+1$		
Planting season	IP_{t+1}, P_t	S_{t+1}, $QF_{t+1,i}$, PC_t
Growing/harvest season	IP_{t+1}, P_t	S_{t+1}, $QF_{t+1,i}$, PC_t
Period $t+2$		
Planting season	IP_{t+2}, P_{t+1}	S_{t+2}, $QF_{t+2,i}$, PC_{t+1}
Growing/harvest season	IP_{t+2}, P_{t+1}	S_{t+2}, $QF_{t+2,i}$, PC_{t+1}
Period $t+n$		
Planting season	IP_{t+n}, P_{t+n-1}	S_{t+n}, $QF_{t+n,i}$, PC_{t+n-1}

IP_t, interim price to be paid on crop delivered in period t; P_t, producer price for crop delivered in period t, equal to interim price adjusted by final payment; S_t, opening stocks of pyrethrum board in period t, equal to closing stocks in $t-1$; QF_t, quantity of food available during growing season of period t, equal to maize harvest in period $t-1$; PC_t, price of other cash crops harvested in period t. Farmers may gain information on current prices for these crops during growing/harvest season, but that information does not affect the pyrethrum production decision.

farmers a certain price when planting decisions are made. To facilitate planning and cash flow, pyrethrum payments are made in two stages. Each year in advance of planting, the pyrethrum board announces an interim price (IP_t) for the coming year's pyrethrum deliveries. Pyrethrum is continuously harvested and delivered for a period of 6–8 months, and mid-year deliveries are to be paid the interim price. Because the board must chemically analyze deliveries for their pyrethrin content before the interim payment is made, there is at least a one month lag between delivery and payment.

If the board has profits at the end of the year, it remits them to the farmers in proportion to their deliveries, without considering the timing of those deliveries. These final payments imply the actual price paid for deliveries from the period t harvest (P_t). The level of the final payment is usually announced after picking has ceased but before the planting of the next crop. [3] If export revenues are lower than anticipated, the board can experience cash flow difficulties. In such cases interim price payments may be delayed and final payments will be negligible. The flow of price information is illustrated in Table 2.

The interim price (IP_t) tends to move with the lagged final price (P_{t-1}) but at a slightly lower level, as the simple OLS regressions in Table 3 indicate. Consequently, sudden changes in the export market can imply a large divergence between the interim and final price for a given year. Between 1980 and 1990, final payments exceeded the initial

[3] Pyrethrum is actually planted in 3 year cycles, but the establishment costs are low and in any year an alternative crop may be planted over a pyrethrum field.

Table 3
Relationship between interim prices and producer prices

$n=29$	Constant	P_{t-1}	Adj. R^2	DW
IP_t	7.27	0.54	0.75	2.01
	(2.3)	(3.9)		
IP_t	–	0.86	0.75	2.01
		(20.6)		

Based on data for 1963–1989 from Pyrethrum Board of Kenya (1959–1989). *T*-statistics are shown in parentheses. Cochrane–Orcutt procedure was applied.

interim price by as much as 30% (1988), while delays sometimes lasted over 2 years (1981).

Delays in payment could be avoided or reduced if the pyrethrum board had access to credit. In practice, failures in the capital markets and regulations on public enterprises exacerbate cash flow difficulties. During the period in question, the Kenyan parliament declined to take actions that would have allowed the pyrethrum board to apply for credit. Internal reserves could also be used to avoid payment delays, but they have been insufficient to do so. [4] Although the real price may be eroded by delay, the Pyrethrum Board of Kenya has never failed to pay at least the nominal interim price, eventually. Why the pyrethrum board selects interim prices that follow the pattern shown in Table 3 is beyond the scope of this paper, but the fact that the price has followed this trend has implications for supply response analysis.

With variation in payments, pyrethrum ranges from being exceptionally profitable relative to coffee, tea, and maize (the main alternative crops) to offering negligible cash inflow and modest eventual net revenues. The profitability levels shown in Table 4 are based on the assumption that delayed payments can be discounted at 12%. Monke et al. (1996) suggest this discount rate as an approximation for the rate of return to capital in Kenya, but they note that smallholders may face much higher costs for short term credit in Kenya's under-developed capital markets. The combination of high potential profits and potential for low or no cash inflow makes it likely that pyrethrum farmers will use all available information to forecast future prices.

The information that can be used to guide production decisions is linked to the crop calendar. The pyrethrum supply decision is largely made at planting. Once land has been allocated, crop yield can be affected through the distribution of weeding and picking labor over the plots. However, in areas best suited for pyrethrum, there are few alternative crops or activities that could be intensified mid-year. Moreover, because pyrethrum plants grow only a few feet tall, most labor is provided by children at low opportunity cost. Child labor is less frequently used on other crops. Consequently, even when pyrethrum payments are lower than expected, labor allocation to the crop may remain stable. In any case, by the first scheduled payment, farmers will have already completed two rounds of weeding (20–30 labor-days per acre) of an average of four rounds and 2 out of 6–8 months of picking (about 25 labor-days

Table 4
Net receipts from alternative cropping activities (Kenya shilling per acre)

	1981	1985	1989
Nakuru (> 8000 ft. elevation)			
Pyrethrum	4800 [a]	5900	7130
Maize	570	885	650
Wheat	1725	1600	1500
Potato	11400	4850	5940
Nakuru (5000 – 8000 ft. elevation)			
Pyrethrum	2140 [a]	3320	4200
Maize–beans	1600	2230	1760
Wheat	2150	2030	1920
Tomato	NA	NA	6000
Coffee	4200	5200	2300
Kisii			
Pyrethrum	3100 [a]	4000	4770
Maize–beans	2900	3400	2950
Bananas	NA	NA	4000
Tea	5040	7300	7100
Coffee	2230	2700	1400

[a] Paid in 1983 and 1984.
Calculated from data in Pearson and Monke (1996). Pyrethrum prices estimated using a 12% interest rate to discount delayed payments. The actual cost of delayed payments may have been greater.
NA, not available.

[4] Data on the inventory and trading reserve were unavailable from 1980 to 1983, but the Pyrethrum Board of Kenya Annual Report and Accounts show the reserve was held at about 20 million shillings from 1975 to 1979 and from 1984 to 1986. According to a Ministry of Agriculture "Price Review" (Republic of Kenya, 1982), in 1982 board revenues fell approximately 200 million shillings short of interim price commitments.

per acre). Since payment delays are less likely at the beginning of the year than at the end, considerable labor may be applied before farmers realize that the final price will be low. Because revision of price forecasts after planting can have only a small effect on output, only information available at planting is relevant for forecasting price. For the purpose of this analysis, information available at planting in a given period is not up-dated in the growing/harvest season of that period, and the final price for the harvest is not known until the next period (Table 2).

4. Empirical model

A generic inverse demand function suggests forecasting prices based on the quantity of pyrethrum available, the availability of substitutes in consumption, and the income of consumers and other exogenous variables. Some of this information is directly available to pyrethrum growers, but a portion of it is available only as it is reflected through their marketing board. The generic model must be modified to incorporate the indirect nature of the information used in forecasting prices. Since supply is responsive to prices paid by the board, producers may be more concerned with a price function indicating the board's payments than with a model of final demand. Consequently, the inverse demand function is replaced with a price formation function which may be influenced by factors not affecting final demand.

Like an inverse demand funcion, the price formation function considers the supply of pyrethrum and substitutes. The availability of pyrethrum is determined by the joint decisions of the producers and is projected using the supply model described below. In the short run, the primary substitute for newly-harvested pyrethrum is pyrethrum extract from the board's inventories. Growers have access to information on these variables through the news media which reports on the disposal of export crops and stocks accumulation during the growing/harvest season. Further information on stocks is provided to growers at delivery points by the board when stocks become unusually high or low.

Discussions with 60 pyrethrum growers in 1989 and 1990 revealed that the producers have very limited information concerning the availability of substitutes, or other factors affecting final demand for pyrethrum products, such as consumer income levels. However, they do see the impact of those factors and some indicators of their current state reflected in the marketing board's behavior. The board's financial status, and thus its ability to make payments, changes with variation in the unmeasured variables that influence final demand. A decline in export demand causes the board to contract increased debt to producers in the form of unpaid interim prices. These payment delays reflect past changes in market conditions, but they also reveal that the board is overcommitted financially and therefore must pay lower producer prices in the future than would be the case if it carried less debt. In discussions, growers tend to interpret the premium between the producer price and the interim price as a signal of the likelihood that future prices will exceed the interim prices and be paid in a timely manner. Payment delays are considered as debts that indicate institutional weakness. Payment performance thus was used as a proxy of financial strength to indicate the direction of future price movements.

During the planting season of period t, the previous year's final price (P_{t-1}) and the previous and current year's interim prices (IP_{t-1}, IP_t) are known. If the final producer price for the previous year was higher than the interim price for that year, the farmer has a clear indication that the board earned enough to cover all its internal costs, maintain sufficient reserves, and return a margin to growers. If the latest realized producer price was close to the corresponding interim price or if there were delays in payment as there were in 1982 and 1983, the farmers have the impression that the board needs to increase its reserve or pay debts and therefore will pay growers a lower share of its receipts.

If the difference between the last producer price (P_{t-1}) and the associated interim price (IP_{t-1}) is used as an indicator of the board's ability to pay, the inverse demand function is replaced with a price formation function indicating prices to be paid by the board [5]:

$$P_t = a + bQ_t + cS_t + d\mathrm{DIF}_t + u_t \quad (11)$$

[5] A more sophisticated price formation function would incorporate a model of how the board selects its interim price and forms its own forecasts of final market conditions.

where Q_t is production in Kenya, S_t represents opening stocks of pyrethrum in the country and DIF_t is P_{t-1} minus IP_{t-1}. Although the DIF term includes past prices, the level of price is not critical as it would be in an adaptive expectations model. Instead, past price differences are significant as they proxy the board's financial strength and indicate upcoming producer payments. DIF could be interpreted as an indicator of past performance which the growers project into the future in an adaptive manner. However, it is reasonable and consistent with farmer comments to see it as an indicator of the current effective demand of the board.

The annual quantity supplied from each district, i, can be expressed as a function of the expected price of pyrethrum given information available at planting time, $E(P_t|I_t)$, the annual rainfall in the district, $R_{t,i}$, the expected price of cash crops, $\widetilde{PC}_t$, and the expected price of food crops in the district, $\widetilde{PF}_{t,i}$. The cost of the primary input, labor, is not included because no time series of rural wage rates is available and there is no indication of changes in the availability of labor. Official prices for maize (the principal food crop) are available, but pyrethrum growers generally buy and sell maize in informal markets where prices often diverge from the official levels. Prices in the informal market are not well documented. Despite grain movement restrictions which may fragment the national cereals market, maize markets appear to be well integrated within districts (Cleaver and Westlake, 1987). Therefore, when the latest $(t-1)$ district maize harvest is poor, maize prices are likely to be high in that district during period t. Using maize harvest in $t-1$ to indicate the incentives to food production during t, pyrethrum supply in each district can be modelled as [6]:

$$Q_{t,i} = g_i + h_i E(P_t|I_t) + k_{1,i} R_{t,i} + k_{2,i} \widetilde{PC}_t + k_{3,i} \widetilde{QF}_{t,i} + \epsilon_{t,i} \quad (12)$$

where R_t is the absolute value of the deviation of rainfall from its mean, PC_t is an index of the combined prices of coffee and tea, and QF_t is the volume of maize harvested in the district for consumption during period t. Because pyrethrum yields are adversely affected to similar degrees by both high rainfall (and the accompanying cloud-cover) and low rainfall, production is expected to be negatively correlated with R (Muturi et al., 1969).

Summing Eq. (12) over all n districts and substituting Eq. (12) into Eq. (11), implies the following expression for price:

$$P_t = a + b\sum_i^n \left[g_i + h_i E(P_t|I_t) + k_{1,i} R_{t,i} + k_{2,i} \widetilde{PC}_t + k_{3,i} \widetilde{QF}_{t,i} \right] + cS_t + d\text{DIF}_t + u_t + b\sum_i^n \epsilon_{t,i} \quad (13)$$

The expectations of the exogenous variables in Eq. (13) must be defined before the expression can be used. These expectations are specified as follows:

$E(R_t) = 0$: expected rainfall over period t is the mean level.

$E(\widetilde{PC}_t) = \widetilde{PC}_t = \text{APC}_t$: an ARMA (2,1) forecast of the value of the coffee and tea price index during period t, using information on prices up to $t-1$.

$E(\widetilde{QF}_{t,i}) = QF_{t,i}$: each district's maize supply that is available for consumption during the growing/harvest season of period t is equal to production in $t-1$ and is known at planting season of period t.

$E(S_t) = S_t$: opening stocks of the pyrethrum board for period t are known at planting season of period t.

$E(\text{DIF}_t) = \text{DIF}_t = P_{t-1} - IP_{t-1}$: previous producer price and interim price are known at planting season of period t.

The estimated model distinguished among three production areas indicated by the subscripts K (Kisii District), N (Nakuru District), and O (other areas, primarily Nyandarua and Kiambu Districts). Taking these expectations to calculate the expected value of Eq. (13) and substituting into Eq. (12) yields the following system for estimation:

[6] Since land allocated to maize will not be harvested until after maize availabilities have changed, response to a low maize harvest in $t-1$ may be increased planting of a faster yielding food crop such as potatoes in period t. Whatever the crop chosen, increased concentration on food provision is expected to reduce pyrethrum production.

$$Q_{t,\mathrm{K}} = \beta_{0,\mathrm{K}} + \beta_{1,\mathrm{K}}\mathrm{APC}_t + \beta_{2,\mathrm{K}} QF_{t,\mathrm{K}} + \beta_{3,\mathrm{K}} QF_{t,\mathrm{N}} + \beta_{4,\mathrm{K}} QF_{t,\mathrm{O}} + \beta_{5,\mathrm{K}} S_t + \beta_{6,\mathrm{K}}\mathrm{DIF}_t + \beta_{7,\mathrm{K}} R_{t,\mathrm{K}} + \epsilon_{t,\mathrm{K}} \quad (14a)$$

$$Q_{t,\mathrm{N}} = \beta_{0,\mathrm{N}} + \beta_{1,\mathrm{N}}\mathrm{APC}_t + \beta_{2,\mathrm{N}} QF_{t,\mathrm{K}} + \beta_{3,\mathrm{N}} QF_{t,\mathrm{N}} + \beta_{4,\mathrm{N}} QF_{t,\mathrm{O}} + \beta_{5,\mathrm{N}} S_t + \beta_{6,\mathrm{N}}\mathrm{DIF}_t + \beta_{7,\mathrm{N}} R_{t,\mathrm{N}} + \epsilon_{t,\mathrm{N}} \quad (14b)$$

$$Q_{t,\mathrm{O}} = \beta_{0,\mathrm{O}} + \beta_{1,\mathrm{O}}\mathrm{APC}_t + \beta_{2,\mathrm{O}} QF_{t,\mathrm{K}} + \beta_{3,\mathrm{O}} QF_{t,\mathrm{N}} + \beta_{4,\mathrm{O}} QF_{t,\mathrm{O}} + \beta_{5,\mathrm{O}} S_t + \beta_{6,\mathrm{O}}\mathrm{DIF}_t + \beta_{7,\mathrm{O}} R_{t,\mathrm{O}} + \epsilon_{t,\mathrm{O}} \quad (14c)$$

$$P_t = \alpha_0 + \alpha_1 Q_t + \alpha_2 S_t + \alpha_3 \mathrm{DIF}_t + u_t \quad (15)$$

$$Q_t \equiv Q_{t,\mathrm{K}} + Q_{t,\mathrm{N}} + Q_{t,\mathrm{O}} \quad (16)$$

with the restrictions that:

$$\beta_{5,i} = \frac{\beta_{6,i}\alpha_2}{\alpha_3} \text{ for } i = \mathrm{K,N,O} \quad (17)$$

The coefficients are identified as follows:

$$\beta_{1,i} = \frac{k_{2,i}(1 - b\Sigma h_j) + bh_i \Sigma k_{2,j}}{\omega} \; j \neq i,$$

$$\beta_{2,i} = \frac{bh_i k_{3,\mathrm{K}}}{\omega} \forall i \neq \mathrm{K},$$

$$\beta_{2,\mathrm{K}} = \frac{k_{3,\mathrm{K}}(1 - bh_\mathrm{N} - bh_\mathrm{O})}{\omega},$$

$$\beta_{3,i} = \frac{bh_i k_{3,\mathrm{N}}}{\omega} \forall i \neq \mathrm{N},$$

$$\beta_{3,\mathrm{N}} = \frac{k_{3,\mathrm{N}}(1 - bh_\mathrm{O} - bh_\mathrm{K})}{\omega},$$

$$\beta_{4,i} = \frac{bh_i k_{3,\mathrm{O}}}{\omega} \forall i \neq \mathrm{O},$$

$$\beta_{4,\mathrm{O}} = \frac{k_{3,\mathrm{N}}(1 - bh_\mathrm{K} - bh_\mathrm{N})}{\omega},$$

$$\beta_{5,i} = \frac{ch_i}{\omega}, \; \beta_{6,i} = \frac{h_i d}{\omega},$$

$$\beta_{7,i} = k_{1,i},$$

for $i = \mathrm{K,N,O}$

$$\omega = 1 - bh_\mathrm{K} - bh_\mathrm{N} - bh_\mathrm{O},$$

$$\alpha_1 = b, \; \alpha_2 = c, \; \alpha_3 = d$$

The expected price of cash crops, APC, is expected to be negatively related to pyrethrum production, as is the level of pyrethrum stocks, S, and rainfall, R. The coefficient on DIF is expected to be positive. High local maize availability is expected to generate increased pyrethrum production locally. The positive impact on local production implies a reduction of price forecasts nationally. Hence, in each district i, the coefficient on $QF_{t,i}$ is expected to be positive while the coefficient on $QF_{t,j}$ is expected to be negative.

District-level production data for pyrethrum and maize are recorded in the Ministry of Agriculture's District Annual Report for each district (District Annual Report: Kiambu, various years; District Annual Report: Kisii, various years; District Annual Report: Nakuru, various years; District Annual Report: Nyandarua, various years). Annual rainfall and coffee and tea prices are recorded in the Statistical Abstract (Republic of Kenya, 1961–1991). Data on pyrethrum stocks, interim prices, and final prices are taken from Pyrethrum Board of Kenya, Annual Report and Accounts (Pyrethrum Board of Kenya, 1959–1989); farmers are assumed to have acquired this information from news media, Pyrethrum Board of Kenya circulars, or direct experience. (There is no statistical support for this assumption, but it is consistent with informal discussions with growers.) Annual data are available for the years 1970 through 1989. All data are expressed in logarithmic form.

5. Results

The relationship between variables in each district and production in every other district creates the possibility for simultaneous equations bias. Therefore, the model with its cross-equation restrictions is estimated as a seemingly unrelated regression system using maximum likelihood and a Cochrane–Orcutt procedure to correct for auto-correlation. The results shown here are based on estimation using SHAZAM (White et al., 1987) which employs a Quasi-Newton algorithm. Results from the restricted and unrestricted versions of the model are shown in Tables 5 and 6.

The log of the likelihood functions of the restricted and unrestricted models can be compared in a likelihood ratio test to determine the significance of the restrictions (Judge et al., 1985, pp. 216, 217).

This test suggests that the restricted model is not significantly different from the unrestricted form ($\alpha = 0.10$), supporting the hypothesis that farmers' expectations are formed in a forward-looking manner as the model suggests.

The level of significance of the coefficients is generally low, possibly due to multicollinearity. (Condition numbers for the individual supply equations were: 123 for Kisii, 121 for Nakuru, and 116 for other districts.) Nonetheless, the elasticity with respect to DIF is highly significant for all areas. The expected price of alternative cash crops is also significant in all production areas. Local maize availability is significant only for Kisii. It was expected that high maize availability in one district would suggest high pyrethrum production in that district, dampening price expectations in other regions. The positive coefficient on Kisii maize in Nakuru contradicts this reasoning. This perverse result probably follows from the pyrethrum growing region in Nakuru (Molo Division) being removed from the maize growing areas of the district and possibly having similar maize production patterns as Kisii.

Table 5
Results of unrestricted model

	Kisii	Nakuru	Other
Supply			
APC_t	−0.88	−0.97 **	−0.74 **
	(1.566)	(2.637)	(2.184)
$QF_{t,K}$	0.77 **	1.31 ***	−0.002
	(2.920)	(3.719)	(0.013)
$QF_{t,N}$	0.04	−0.07	0.05
	(0.445)	(0.784)	(0.856)
$QF_{t,O}$	0.16	−0.18	−0.15
	(0.752)	(1.048)	(0.923)
S_t	−0.02	−0.04	0.10
	(0.213)	(0.754)	(1.536)
DIF_t	4.26 ***	3.69 ***	1.18 ***
	(8.517)	(5.867)	(3.984)
R_t	−0.07	−0.08	−0.03
	(0.668)	(1.408)	(0.510)
Demand			
$Q_{p,t}$	0.046	0.046	0.046
	(0.370)	(0.370)	(0.370)
S_t	−0.07 **	−0.07 **	−0.07 **
	(2.716)	(2.716)	(2.716)
DIF_t	0.35 *	0.35 *	0.35 *
	(1.724)	(1.724)	(1.724)
Log of likelihood	39.16	39.16	39.16

T-statistics in parentheses: *, **, *** indicate significance at 10%, 5%, and 1%, respectively.

Table 6
Results of restricted model

	Kisii	Nakuru	Other
Supply			
APC_t	−0.86 *	−0.70 *	−0.81 **
	(1.964)	(2.013)	(2.543)
$QF_{t,K}$	0.61 **	1.20 ***	0.04
	(2.262)	(4.719)	(0.249)
$QF_{t,N}$	−0.01	−0.09	0.04
	(0.160)	(1.218)	(0.604)
$QF_{t,O}$	0.12	−0.18	−0.19
	(0.693)	(1.146)	(1.146)
S_t	−0.25	−0.21	−0.08
DIF_t	3.68 ***	3.23 ***	1.28 ***
	(7.389)	(6.183)	(3.982)
R_t	−0.10	−0.08	−0.03
	(1.174)	(1.641)	(0.586)
Demand			
$Q_{p,t}$	0.10	0.10	0.10
	(0.802)	(0.802)	(0.802)
S_t	−0.02 *	−0.02 *	−0.02 *
	(1.801)	(1.801)	(1.801)
DIF_t	0.37 *	0.37 *	0.37 *
	(1.921)	(1.921)	(1.921)
Log of likelihood	38.14	38.14	38.14
Likelihood ratio test (χ^2)	2.06	2.06	2.06

T-statistics in parentheses: *, **, *** indicate significance at 10%, 5%, and 1%, respectively.

6. Discussion and conclusion

If no information other than past prices is available to farmers at acceptable cost and timeliness, adaptive models are suitable for supply response analysis. If, on the other hand, farmers have easy access to information about the underlying market dynamics that generate price changes, models that represent farmers as forward-looking economic agents may be appropriate. Use of a model that more accurately reflects farmers' forecasting methods will result in more accurate supply response analysis. When farmers use information about markets that is filtered through a formal institution, the modelling approach may also influence the design and implementation of marketing policy reforms.

Support of the rational expectations hypothesis in the case of Kenyan pyrethrum suggests that African smallholders use information other than past prices when making price forecasts and supply decisions. In this application, the significance of the DIF coefficient suggests substantial supply responses to changes in the board's financial status or management. Minor changes in management of the interim prices could alter the informational content of the DIF variable and undermine forecasts. Consequently, reforms in the management of the board or in the marketing system in general may cause farmers to misinterpret market information. During periods of market reform, increased forecasting errors may affect production decisions at least until the new marketing system is understood. Perturbations to the price forecasts and supply decisions can be reduced by making any marketing reforms as transparent as possible. Transparency of reform probably implies gradual change rather than sudden restructuring.

The potential for institutional reform to affect price forecasts is greatest when producers use information that is channeled through and altered by a monopsonistic marketing board. Reliance on such information could follow from lack of access to or understanding of the final market, which is probably the case for industrial and specialty crops grown by smallholders. The exact mechanism through which information suitable for forecasting is transferred will vary from case to case, but disrupting that mechanism is likely to have undesired consequences for price expectations and supply response in the short run. If farmers have direct access to information on the final market or if domestic policies and institutions allow that information to flow undistorted to the farmer, then market reforms should not affect forecast accuracy, even in the short term.

Analytical methods that explicitly consider the farmers' impressions of relevant institutions and other current information often provide greater insight into production decisions than do adaptive models. The example of Kenyan pyrethrum indicates that when a marketing board has control over a large share of the market, even smallholders may have access to the information needed to form forward-looking price forecasts. That information can include indicators of aggregate demand and (especially when the small country assumption does not hold) projections of future supply conditions. By allowing the possibility that small-scale farmers use a wide information set to forecast prices, analysts may gain an improved understanding of the dynamics of agricultural supply response in developing countries.

Acknowledgements

The author is grateful to Scott Pearson, Jeffrey Williams, and an anonymous referee for comments on earlier drafts of this paper.

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