Real exchange rate price and agricultural supply response in Ethiopia: The case of perennial crops

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Abstract

In this study the relationship between RER, price and supply response of coffee is described in detail. The objective is to see if devaluation affects RER agricultural price and supply of coffee—a perennial crop that is the major source of foreign exchange of Ethiopia. After developing a model of perennial crop supply, panel data were gathered from small-scale farmers. Both descriptive statistics as well as the econometric estimates (where fixed effect model was applied) showed that there was positive response for both the short run and the long run. In the former farmers were able to increase yield through increased use of labour and fertilizer on existing stock of trees. There was also an increase in the uprooting of old trees and replacing them by new ones, as well as the use of extra acreage at the expense of other perennials and annuals.

I. Effect of devaluation on the Ethiopian macroeconomic performance

In a previous study (Kidane, 1994) I described the impact of Ethiopia's decision to follow a fixed and predetermined nominal exchange rate pegged to the U.S. dollar. This led to the over-valuation of the Ethiopian currency; the birr, which in turn resulted in an ever increasing budgetary deficit. The government was forced to balance the deficit through money creation. The fixed exchange rate also led to the increase in domestic credit, which enhanced demand for tradeable and non-tradeable goods. While the former led to higher trade deficit, the latter resulted in higher prices. This chain of events eventually worsened the exchange rate misalignment and further over-valuation of the Ethiopian currency. The process continued to characterize the Ethiopian economy in the 1970s and the 1980s. Since this trend was not reversed, the over-valuation or appreciation of the exchange rate as well as the inconsistency between monetary and fiscal policy on the one hand and the exchange rate misalignment on the other continued unabated.

During the crisis period (1974–1991) the Ethiopian government tried to contain the process not by following appropriate policies that could bring the disequilibrium and inconsistency back to sustainable equilibrium and internal consistency, but by imposing further exchange controls and higher export and import duties, as well as further nationalization at the expense of private incentives and the operation of market forces. These controls and impositions led to the emergence of parallel markets and further increase in budgetary deficit. Between 1974 and 1991, the ratio of the parallel to the official market exchange rate of the Ethiopian currency increased from 1.71 to 3.63. The expenditure– revenue ratio increased from 0.83 in the late 1950s to 1.34 in the late 1980s.

In May 1991 when the transitional government was installed in Ethiopia, the new leadership agreed to undertake economic reforms prescribed by the International Monetary Fund and the World Bank. The reform package included reorganization of state owned enterprises and marketing boards in order to eliminate protectionism and give incentives to the production of tradeable goods. Most important, the birr was devalued by 242% and a bi-weekly foreign exchange as a major tool for bringing about economic growth and stability.

The reform is now three years old and some preliminary indicators show that results are so far satisfactory. During the first two years GDP growth changed from negative to positive, and the balance of payments position showed some improvement especially in the volume and value of exports as well as capital inflow. Most important the exchange rate premium was reduced from 3.63 to 1.13 while the rate of inflation did not show substantial increase (Kidane, 1994).

An attempt was made to model the monetary or price effects of devaluation on the price of tradeable and non-tradeable goods and the real exchange rate (RER). The results showed devaluation and the reduction in premium as the two most important variables explaining the variations on the relative prices of tradeables, non-tradeables and the RER in a predictable manner. The effect of devaluation on real variables was also considered and the results showed that the effect of devaluation (as reflected in the variation of RER) on the supply and export of coffee seems to be positive and significant. The results suggest a substantial reduction in coffee smuggling and an increase in the export of coffee through official channels. Other short-run and long-run responses to changes in RER were not considered because of the recentness of the reform and the nature of Ethiopia's major export commodity – coffee, a perennial crop. It is now possible to study supply response by considering both short-run and long-run time frames. This study considers the relationship among the real exchange rate, prices and agricultural supply response in Ethiopia. The commodity of focus is coffee. In the following paragraphs we review the major issues pertaining to short-run and long-run responses of a perennial crop. This is followed by considering the importance of coffee as a major foreign exchange earner in Ethiopia. The methodology used involves developing an econometric model, identifying methods of data collection, and preparing descriptive statistics of both time series and cross section data related to price, production and supply of coffee. Analysis and policy implications follow.

II. The economics of perennial crop supply

Production and supply of perennial crops have been studied by several authors, including Akiyama and Thrivei (1987) Thrivei and Akiyame (1992), Thrivei (1992), Weaver (1989), Ssemogerere (1990), Berry (1976), Wickers and Greenfield (1973), French and King (1971), and Bateman (1969, 1965). Many of these studies use models that take into account both short-run and long-run responses, as well as relevant macroeconomic and microeconomic theories. Once the models are constructed, reduced forms are derived and empirically tested. The estimated results usually include both short-run and long-run price (own and related prices) elasticities. In studying the economics of perennial crops short-run responses refer to changes in supply from a fixed stock of capital consisting of the existing number of trees. Long-run responses refer to changes in capacity. In other words, the issues related to short-run responses are not different from those pertaining to annual crops. In such a case the variable inputs are use of fertilizer and labour. The short-run consideration is, therefore, the alternative renumerative activities for such inputs.

When the long-run responses to perennial crops are taken into consideration supply responses become more complicated. This is because one may have to make some assumptions about the expected future earnings. In the long-run responses the issues are similar to the theory of investment and replacement, which incorporates expectation formation and various trade-offs. Long-run responses also have to deal with formulating models for tree removal, for replanting and for new planting, as well as for increased acreage.

Issues in long-run supply responses

Issues in the economic analysis of long-run responses to perennial crops revolve around expectation formation, present value calculation, the trade-off between present and future income, and the trade-off between asset value and change in income. Expectation formation involves the consideration of several variables: farmers face uncertainties about price and exchange rates, yields, wages, inflation and government policies. In other words, the decision to plant a coffee tree will have meaning only if one considers the future. Studies on perennial crop supply assume some relationship among prices in the near past, those in the present and those expected to prevail in the future. Because of this, several authors assume that a change in the expected price is proportional to the difference between the last actual price and the last expected price; in other words, they use an adaptive expectation formation. Other authors treat expectation formation differently by hypothesizing that high present prices induce postponement and uprooting while an expected increase in prices may result in replanting.

It is also possible to use present value calculation as a means of making decisions about tree planting. For example, in considering new planting farmers need to estimate what yields are to be expected and in which years. Yields are typically non linear, with zero in the first few years and subsequent increases that reach a peak and then decline again. The net present value with an appropriate discount factor indicates the present value of the project. It is interpreted as being similar or equal to the price one would get if a farmer sold the rights to the future stream of income. Issues such as the effects of uncertainty and use of an appropriate time frame are also taken into consideration.

Besides the present value calculation farmers may make decisions each year in such a way that a decision made this year will not make next year's decision difficult or costly.

Supply responses of coffee

Coffee is one such perennial crop; it begins to yield three years after planting and has a production life of up to eight years. The harvesting process follows an inverted U shape, that is, low yield during third and fourth years followed by maximum yield in the fifth and six years, and finally a low yield during years seven, eight and afterwards. Naturally the stated yield may vary with the timing of planting, the fertility of the soil and the technological inputs. It may be possible to model coffee production via investment decision processes whereby one may have to weigh present and future income as well as trade-off between a set value and change in income. This approach is not pursued here as the aim is to study supply responses only.

For coffee, farmers' calculations involve whether postponing of replanting and continuing tapping will be more profitable than investing in new trees now. The decision rule would be to postpone when income is higher than the interest over the net present value. The problem here is while income is almost certain, interest on net present value may be uncertain. Some farmers may decide against planting coffee because they may envisage other profitable crops to grow in the early years to come. Other farmers may be more interested about their future position. This may be a function of the age of the decision makers themselves; for example, older farmers are less likely to place high value on future expected income than are younger farmers. Besides age, the life cycle of farmers may also be important: for middle-aged farmers new tree planting may guarantee them income without much family labour at later ages; the discount factors may also depend on the age of the farmer.

Besides the trade-off between future and present income, there may also be a trade-off between asset value and change in income. We note that the net present value of tree growing should be higher than other feasible investment alternatives. A farmer with particular skills and other endowments may prefer investing in annual crops; if the land is suitable for other crops or if the climate and marketing opportunities are favourable to other perennial crops, then the farmer may also consider other tree crops besides coffee.

Here the net present value of coffee may have to be compared with alternative tree crops. The farmer may still be in favour of planting coffee if the present income is less than the interest over the net present value of the planting and the net present value of his present tree crops. The latter requirement implies that farmers with recently planted trees will not start new planting because the net present value of the recently planted trees is higher than the corresponding value of new plantation.

This discussion suggests that the economics of perennial crop supply is rather complicated and can be approached from different angles. In all the approaches, the past, present and future producer prices of the crop play a crucial role in the decision to remove, replant, plant a new crop, or increase the acreage.

Information on these decisions is limited. Most SAP related response studies have dealt with annuals and little attention has been given to perennial crops. Even though some supply response models have been applied to cocoa and coffee in some West African countries, such models did not give attention to the particular characteristics of such tree crops. Moreover, unlike the perennial crop models that have been applied for advanced countries, there are unique land tenure characteristics for Ethiopia and other developing countries and this may justify modifying the existing models.

Coffee in the Ethiopian economy

Ethiopia has always depended heavily on coffee for export and tax earnings, although the latter was lifted in 1992 as a result of economic reforms. During the past 30 years and earlier coffee constituted about 60% of export earnings, and tax from coffee exports increased while the price increase was not relatively high. Table 1 shows export earnings as well as share, tax revenue and price of coffee for selected periods.

Table 1: Export earnings, share, tax revenue and the price of coffee in Ethiopia (1960-1990)

Years	Earnings (in million birr)	Share	Tax revenue (in million birr)	Price
1960	93.4	0.48	5.1	22.1
1965	188.2	0.65	13.129.8	
1970	181.2	0.59	20.132.8	
1975	152.7	0.32	18.432.2	
1980	563.9	0.64	77.443.0	
1985	432.7	0.62	121.547.8	
1990	272.2	0.44	79.8	49.5

When the empirical results presented in Table 1 are compared with the overall macroeconomic performance one may observe that the two are closely related and Ethiopia may continue to depend on this tree crop as a source of foreign exchange earnings. In order to improve the international competitiveness of this commodity as well as to give more incentive to coffee producers, the new macroeconomic reform includes reducing the dominance of the government operated coffee marketing board, giving private traders the license to trade and export coffee and—most important— devaluing the birr by 242%. The devaluation resulted in increased producer prices of coffee by 112% over the past 24 months. Administered prices and tax on exports have also been eliminated, thereby enabling prices to reflect marginal export revenue as well as realigning prices with domestic production costs. In Ethiopia coffee is produced in the same area along with annual crops and it is possible to postulate potential substitution between this perennial and the annuals.

Even though coffee is the main foreign exchange earner in Ethiopia there is not to date information on variables such as the number of coffee growers, area under coffee, yield of coffee per hectare and employment in coffee culture. Estimates of areas under coffee cultivation (Kahli, 1981) ranged from 204,500 to 683,600 hectares. The number of growers is estimated to be about one million, with more than 80% of them classified as small growers. The average yield per hectare is between 340 and 490 kg. At the same time, annual coffee consumption per household in the country is 24.5 kg and the per capita consumption is 4.5 kg.

In general, the area under cultivation is considerable while the yield is far below average. Thus supply response as a result of increased domestic price of the commodity could come about through increased productivity or reduced domestic consumption. This is in addition to possible increase in acreage, removal and replanting.

III. Study description

The overall objectives of this study are to study the response of coffee farmers to changes in the domestic price of coffee. The change has come about as a result of the recent economic liberalization in general and of a 242% currency devaluation in particular. It was already observed (Kidane, 1994) that the producer price of coffee has increased from 2,286 birr per metric ton during the pre devaluation period to 4,729 birr afterwards—an increase of 112%. Compared with the price of cereals (a non-tradeable), the price of coffee showed an increase of 110%.

With this background in mind it is in order to investigate whether the Ethiopian farmer's response to a price incentive is positive and in the expected direction. To this effect we studied both short-run and long-run responses.

Regarding short-run responses we studied:

1. Whether farmers use increased amounts of fertilizers, more family labour or hired labour, or whether the intensity of tapping has been accelerated.

2. Whether the use of such inputs was at the expense of other remunerative activities such as other annual crops or employment outside agriculture.

An econometric model that is appropriate for studying both short-run and long-run responses was developed and subjected to empirical verification. The model applied in the short run is simple and straightforward. Modeling long-run responses is more complicated; the basic features of the model are described later.

Significance of the study

Most economic reform programmes in Africa are producing mixed results; the optimists state that the reforms are showing the desired outcomes, but others think otherwise. There are several reasons for this divergence of views. One reason may be the method of evaluating the outcomes of the reforms. The most objective approach would be to present the theoretical issues clearly, use sound macroeconomic reasoning and formulate a scientific means of evaluation. As the reforms are many and varied, evaluations have to be done by considering one issue at a time.

In this exercise we study the effect of devaluation and the corresponding increase in the real exchange rate on the supply of coffee—the main foreign exchange earner of

Ethiopia. Our findings could have important effects on subsequent macroeconomic policy formulation. If the effect of devaluation is showing the desired results, then the issue may be how to achieve such results within a relatively shorter period. If, on the other hand, the desired results are not forthcoming, further devaluation may be suggested, or institutional bottlenecks may be identified or other new incentive schemes may be introduced. The aim here is to evaluate one aspect of the economic reform, the effectiveness of exchange rate realignment on the performance of the coffee sector. The results should enable policy makers to make adjustments and revisions in policies.

Data sources

The study used two sources of data, secondary and primary. The secondary source is data on coffee production, acreage, domestic consumption and export. Most of such information is already available with the Ministry of Coffee and Tea Development of Ethiopia. The data are both time series and survey or cross section. Although secondary data may not enable us to empirically implement the econometric model that has been specified, they may give us some indication on the past and current situation of the coffee sector and its importance on the Ethiopian economy.

In order to answer the objectives that we set and also to empirically implement the reduced form of our model, we collected farm level data by administering a questionnaire designed for this purpose. The survey which was conducted in March 1995, was confined to the coffee growing areas of the country; a copy of the questionnaire is included in Appendix A. Even though the questionnaire is brief, it is unique in the sense that it enables us to measure the variables that are necessary for estimating supply response equations as described earlier.

The survey sample size is 300 households, from which 276 responses were found to be fit for analysis. The method of sampling was both purposive and scientific. First, we identified regions that are fair representatives of the coffee farming areas of the country. Thus the first stage is purposive. Once the regions were identified, we chose households that represented various demographic and socio-economic categories such as small, medium and large size households. A proportional sampling method was adopted in the second stage.

Descriptive statistics of price variables

Trends in parallel market premium

Table B1 in Appendix B shows the trends in the official and parallel market exchange rates, as well as the exchange rate premium. One can observe that since the October 1992 devaluation the difference between the official and parallel market exchange rate has narrowed from 3.5 to one to only 1.5 to one. In many African countries the effect of devaluation on the reduction in premium seems to be realized only in the short run; eventually the premium widens and misalignment takes place again. In the Ethiopian case the realignment has been maintained over the past 30 months; a premium still exists, but at a much reduced level.

Trends in the real exchange rate (RER)

We have already identified various direct and indirect measures of RER. In this study we have defined RER as the ratio of the price of tradeables to that of non-tradeables. As stated earlier, the measurement of RER requires identifying a basket of tradeable and non-tradeable commodities, having a composite price for each set, and then getting the ratio of the two. In such an undertaking it may be difficult to identify which commodity is tradeable and which is not. This difficulty is partially resolved by taking into consideration the Ethiopian setting. In Ethiopia coffee accounts for more than 75% of Ethiopian export earnings, and all cereals are consumed domestically. The ratio of these two sets of price indexes will show trends in RER movement in Ethiopia. One can clearly see in Table B2 in Appendix B that since October 1992 the RER has appreciated significantly, suggesting that the expected response from farmers is likely to be positive.

Trends in farmgate and international price of coffee

One may also observe a positive trend in the convergence between the farmgate price and the international price of coffee. This estimate was done before and after devaluation. A converegence between the two trends may indicate that non price variables, market rigidities, institutional bottlenecks, and different types of taxes and tariffs may have been eased or liberalized. It should be noted that there is no explicit or implicit government subsidy to small-scale coffee growers. The results (which are not shown) do not seem to show substantial convergence before and after devaluation. In other words, devaluation and foreign exchange rate realignment do not seem to be followed by other forms of economic liberalization.

IV. Survey results

There are five major coffee growing areas in Ethiopia: Keffa, Illubabor, Wollega, Hararghe and Sidama zones. Most of these are located in eastern, southern and southwestern Ethiopia. We randomly selected Sidamo region; the use of simple random sampling during the first phase of sampling was determined by the fact that there is not much variability among the five zones in terms of basic characteristics of smallholder farmers such as the land tenure systems, the size of land owned and cultivated, the daily wage rate, transport between the regions and the capital city. Within Sidamo zone there are six subregions and two of them were again selected randomly. The third stage of sampling involved proportional samples of 180 and 92, respectively, from each subregion.

The major problem involved in the administration of the questionnaire was the inability of respondents to recall information more than two years back. Another major problem was the distribution of the available acreage of a typical household between coffee and other perennial and annual crops. In some instances it was common to observe annual crops being planted within acreage allotted for perennials. Besides, acreage does not seem to be a good measure of the extent of planting coffee and other perennial. This is because within one hectare one may observe a number of different planted tree crops. Thus the best method of considering tree replanting and removals is to estimate the number of coffee trees and other perennials for past, current and future periods. Other problems associated with coffee planting at the study site—as well as other areas—is the smallness of acreage at the disposal of farmers. This would have a negative effect on farmers' intentions to expand or plant annual crops. The land tenure system that is practiced does not allow for easy acquisition or disposal of farmland. The land is periodically and equitably distributed among the peasants; once allotted, a farmer can use the land for a long period. The farmers' children can inherit the land, but the land cannot be sold or used as collateral.

In spite of these shortcomings, the quality of the collected data set seems to be satisfactory and within acceptable limits. This may be verified by observing the descriptive statistics in Section 2.

The following sections summarize the small-scale farmers' responses to the survey about their actions over the past two years and their expected response during the survey period. We have already noted that the economic liberalization programme in Ethiopia has several components, and that devaluation and the corresponding change in the real exchange rate, as well as change in the price of coffee, are some of the variables that affect farmers' decisions about the output of tradeable commodities.

Sale of coffee by small-scale farmers

Trends in the sale of coffee by small-scale farmers during the current and last year are given in Table 2. It should be noted that sales during the current year are the outcome of harvest during the past year. Also, last year's sales are the result of harvest during 1993. In other words, last year's sale of coffee is the response one year after currency devaluation and current year sales are responses two years afterwards. On average, there is an increase in sales of about 87 kg per farmer, but about 51% did not respond to price change one year after devaluation. This percentage decreased to 34% two years after devaluation.

Table 2: Coffee sold by small-scale farmers

	Number of respondents	
Amount in quintals	Current year	Last year
0	87	127
0.1-0.2	119	85
2-4	23	24
4-6	7	6
>6	13	7
Total	249	247
Mean	2.651.78	
SD	4.44	3.45

Source: Survey results.

Number of coffee trees owned by small-scale farmers

The number of coffee trees owned by small-scale farmers this current year is more than last year by only 2%. In other words, the increased sales have been the result of intensive picking and use of modern inputs and hired labour, and this response seems to be of a short-run nature. This is shown in Table 3.

Use of fertilizers and insecticides

In general, small-scale farmers in the study area use less fertilizer on coffee farms than on their annual crops. Within coffee farms, the use of fertilizers last year was higher by 6% than two years ago; this is shown in Table 4 below. Insecticides are used more for coffee than for other perennial or annuals. The results show that one year after devaluation only 7.9% of coffee farmers used insecticides; this increased to 13.77% two years after devaluation.

Table 3: Number of coffee trees owned by small-scale farmers

No. of trees	Current year	Last year
0-100	35	34
100-250	23	29
250-500	63	6
500-750	16	15
750-1,000	36	36
1,000-	54	57
Total	227	227
Mean	1033.11	1011.94
SD	1414	1375.107

Source: Survey results.

Table 4: Use of fertilizers and insecticides by small-scale coffee farmers

	Last Year		Two years ago	
	Fertilizers	Insecticide	Fertilizer	Insecticide
Not using	174(63.4)	238(86.23)	204(73.65)	254(92.03)
Using	102(36.6)	38(13.77)	73(26.35)	22(7.97)
Total	276(100)	276(100)	276(100)	276(100)

Values in parentheses are percentages.
Source: Survey results.

Use of hired labour

Small-scale farmers in the study area mostly depend on household labour, with hired labour usually used during coffee picking season. Table 5 shows that the number of workers hired last year was slightly more than that of two years ago. Two years ago, 83% of small-scale coffee farmers did not hire wage labour at all. This percentage was reduced to 78% last year.

Table 5: Use of hired labour by small-scale coffee farmers

No. of workers	Current	Last year
0	216	229
0-2	14	8
3-5	24	16
6-9	7	8
10-	15	15
Total	276	276
Mean	1.631.54	
SD	5.01	5.13

Expected number of trees planted or uprooted

Small-scale coffee farmers were asked the number of new coffee trees they expected to plant as well as the number of old trees they expected to uproot. Answers to this question are meant to indicate the long-term direction towards increasing coffee yield. The response is given in Table 6. The result shows a substantial difference between planting new trees and uprooting old ones. On average, farmers expected to plant about 306 new coffee seedlings, compared with about 63 they expected to uproot. While 20.5% of the respondents said that they did not intend to plant new trees, about 46% stated that they did not intend to uproot. This result suggests that overall small-scale farmers intended to plant more trees; this may be done either by making intensive cultivation within existing coffee farms or by planting extra acreage at the expense of other perennial or annual crops, or a combination of the two.

Table 6: Expected number of tree plantings and uprootings

No. of trees	New tree planting	Tree uprooting
0	56	124
1-100	68	118
100-250	46	17
250-500	46	17
500-750	7	1
750-1000	20	0
>1000	11	1
Total	272	272
Mean	305.91	63.39
SD	422.02	306.88

Source: Survey results.

In general, both secondary and primary source statistics show that devaluation followed by increase in the price of tradeables tended to give the desired result. The tables indicate that farmers do respond in the desired manner and that the responses seem to be of both short- and long-term nature.

V. Modeling a long-run response for perennial crops

In the preceding section we noted that the production of a perennial crop involves planting, removal, yield and time dimensions; such issues are not encountered in annual crops. In order to adapt standard economic theory to study supply response to coffee in Ethiopia, it is necessary to develop a model that provides a structural base for estimating response relationships and incorporates the various dimensions of the responses. Like other similar studies, the model used here is based on rational producer behaviour that takes into account possible actions of other producers.

The model is adapted from concepts used in previous applied and incorporates the distinguishing characteristics of a perennial crop as opposed to an annual crop. The major differences are:

- Long gestation period between initial input and outputs.
- Extended period of output.
- Gradual deterioration of the productivity of the trees.

Because of these distinguishing characteristics, the model for perennial crop supply response should be able to incorporate planting, removal and replacement decisions, and take into account the lags between input and output. The model that we apply here was developed by French and King (1971) and has five components. We consider only the four components that are relevant to this exercise:

- Equations that explain desired production and acreage.
- New plantings equation that shifts average towards the desired level.
- An equation that explains acreage removed each year.
- An equation that explains variation in the values of average yields.
- Detailed econometric specification is given in Appendix C.

Some methodological issues

There are two major methodological issues that relate to the estimation process of the model described in Appendix C. These issues deal with pooling cross section and time series data as well as the estimation of distributed lag models that characterize the equations of the perennial crop models. Before the empirical implementation of the model we consider these two issues.

Lagged variables

The model of supply response of perennial crops described in the earlier section includes not only observed but also expected variables. This recognizes that a given period of time may have to elapse between the movement of the explanatory variables such as price and the response of the dependent variable such as supply of coffee. This is more so in time series analysis. In other words, it will take some time to realize the final impact of a new policy such as a change in the real exchange rate on the decision-making process of small-scale farmers. This is especially so if the responses take a longer time; in such a case the explanatory variables may have to be lagged by one or more periods. A one-period lag may allow the time involved in supply responses to change in price. The specification of lag structure within the supply response model may depend on the time unit of the data. If the period of measurement is larger than the reaction period, then the process of lagging may not be necessary; on the other hand, long-run supply responses of perennial crops may have a longer reaction period than the period of measurement of the data set and therefore lagged dependent variables will have to be included among the explanatory variables. The aim here is to take into account long-run supply changes that take place gradually over time. When applying distributed lag models one should recognize and identify some prior conditions about the structure and form of the distributed lag. There are several forms of distributed lags, including the geometric lag, polynomial distributed lag and stock adjustment model. Detailed descriptions and properties of these forms are provided elsewhere.

Pooling cross section and time series data

We have already noted that the major source of data is primary or cross section. To this effect we collected data from a sample of 276 small-scale farmers in major coffee producing areas. The results show sufficient variability in many of the relevant variables such as household and hired labour, acreage, trees existing, uprooted or replanted, and the use of fertilizers and insecticides, as well as other variables. On the other hand, prices do not show much variability in a short period, as many small-scale farmers are price takers. Recently high variability in price was realized over a period of time; this was the result of government policy of realigning the exchange rate and the resulting variation in real exchange rate. This implies that one may have to pool cross section non-price and time series price variables while empirically estimating the relevant coefficients in the model. Pooling two sets of data poses a problem of model specification; this in turn may negatively affect the desirable properties of the error terms. When combining the two data sets, there will be three types of error terms: cross section related error terms, time series related error terms and error terms related to the combined data set.

There are several methods of pooling the two sets of data. The first method involves combining both sets and performing OLS. The second method is known as the covariance analysis; here a dummy variable is introduced to take into account price variability for a given cross section data set that is up for empirical implementation. A more complicated but scientifically sound approach would be to rewrite the model by taking into account the existence of the three error terms mentioned above with a view to increasing the efficiency of the OLS estimation process. The technique used here belongs to a family of generalized least square (GLS) estimation processes. Other alternative methods of pooling could also be considered. The three methods of pooling cross section and time series data are summarized below. More emphasis is given to the error component method as this is the one we apply in this study.

Cross section and time series data. Consider the following model:

$$Y_{it} = \alpha + X_{it}\beta + \varepsilon_{it} \tag{1}$$

i = 1,2.......... N
j = 1,2.......... T

Where Y_{it} = a set of explanatory variables corresponding to farmer i at period t

X_{it} = a set of explanatory variables corresponding to farmer i at period t

ε_{it} = error terms with the desired properties.

Assuming that all OLS assumptions concerning the error term hold, one can estimate T regressions for each cross section data set. If a and b remain constant over both cross section and time series data sets, the data can be combined so that the total number of observations is NT.

The covariance model. The preceding assumption that the regression coefficients will remain constant across groups and over a period of time is usually not tenable. In a dynamic model analysis where individual farmers are expected to make short-run and long-run adjustments to price changes and non-price incentives, one should naturally expect a change in the regression coefficients at least over time. In such a scenario a dummy variable may have to be introduced to capture the change in the coefficient s over time and over cross section units. The introduction of a dummy variable could be implemented if one assumes a change in either or both the regression coefficients. This approach is known as covariance analysis and may be written as follows:

$$Y_{it} = \alpha + X_{it}\beta + \gamma_2 W_{2t} + \gamma_3 W_{3t} + \ldots + \gamma_N W_{NT}$$
$$+\delta_2 Z_{i2} + \delta_3 Z_{13} + \ldots + \delta_T Z_{iT} + \varepsilon_{it} \qquad (2)$$

Where $W_{it} = \begin{cases} 1 \text{ for ith individual. i = 1,2,..., T} \\ 0 \text{ otherwise} \end{cases}$

$Z_{it} = \begin{cases} 1 \text{ for period t. t = 2,3,..., T} \\ 0 \text{ otherwise} \end{cases}$

The model has dummy variables with (NT-T-N) degrees of freedom.

The choice of the covariance model over a straight pooling can be decided upon the application of an F test. Because Equation 1 has more restrictive assumptions one should expect higher sum of squares of the error term component to Equation 2. If there is no significant difference between the two sums of squares, one may conclude that the restrictions on equation 1 are in order and OHS can be applied. The F statistic used to compare the two sums of squares is given by:

$$F_{N+T-2,NT-N-T} = \frac{\left(\dfrac{ESS1 - ESS2}{N+T}\right)}{\left(\dfrac{\dfrac{ESS1}{ESS2}}{NT-N-T}\right)} \qquad (3)$$

Where ESS1 = sum of squares from error terms in Equation 1
ESS2 = sum of squares from the error terms in Equation 2

Even though the covariance model introduces dummy variables to account for changes in the value of the regression coefficients over time and across observations, the dummies do not help us identify which of the variables are the cause of the shift. In other words, dummy variables are only proxies for missing variables and thus difficult to interpret. A better approach will thus be the error component model, which is summarized below.

The error component model. Consider the following model:

$$Y_{it} = \alpha + X_{it}\beta + V_i + \varepsilon_{it} \quad (4)$$

i = 1,2,............,N
t = 1,2,............,T

Where

Y_{it} = response of farmer i at period t

X_{it} = a set of explanatory variables corresponding to farmer i at period t

V_i = farmer specific residual. These variables differ among farmers; for a particular farmer the value is constant.

ε_{it} = an error term with the usual OHS properties.

From Equation 4 we can obtain the following:

$$\overline{Y_i} = \overline{X_i}\beta + V_i + \overline{\varepsilon}_i \quad (5)$$

Where

$$\overline{Y_i} = \frac{\sum Y_{it}}{T_i}$$

$$\overline{X_i} = \frac{\sum X_i}{T_i}$$

$$\overline{\varepsilon_i} = \frac{\sum \varepsilon_i}{T_i}$$

Equation 5 is known as a "between effect". It describes the response of a typical farmer over study period T_i and may give us insight into long-run supply response. Subtracting Equation 5 from Equation 4 we obtain the following result:

$$Y_{it} - \overline{Y_i} = (X_{it} - \overline{X_i})\beta = \varepsilon_{it} - \overline{\varepsilon_i} \quad (6)$$

Equation 6 is typically known as "within effect" and may describe the short run responses. It is also known as a "fixed effect model". In general, equations 4, 5 and 6 form a basis for estimating β.

The overall effect or the "random effect model" is obtained by having a weighted average of equations 5 and 6. This is given in Equation 7:

$$(Y_{it} - \theta \overline{Y}_j) = (1-\theta)\alpha + (X_{it} - \theta \overline{X}_t)\beta + (1-\theta)v_j + (\varepsilon_{it} - \theta \overline{\varepsilon}_i) \tag{7}$$

Where θ is a weight and its value is a function of σ_v^2 and σ_ε^2, and σ_v^2 = 0 (that is, if v_i and θ are always zero, then we can apply Equation 1). If σ_ε^2 = 0 (that is, ε_{it} = zero and θ = 1 then "within" estimate gives all the information. In our case, θ = 1 implies that farmers do not respond to prices at all. Naturally these are two extreme values and more reasonable cases are somewhere between the two.

We now consider a variation of Equation 7 of the following form:

$$Y_{it} = \alpha + \overline{X_i}\beta_1 + (X_{it} - \overline{X_{it}})\beta_2 + v_i + \varepsilon_{it} \tag{8}$$

Equation 8 considers both the "between" and the "within" effects or, respectively, the long-run and short-run effects. In our study, β_1 is an indicator of long-run supply response to price changes while β_2 may capture the short-run or transitory effects.

Corresponding to Equation 8, the variation of equations 6 and 7 will be:

$$\overline{Y_i} = \alpha + \overline{X_i}\beta + v_i + \overline{\varepsilon_i} \tag{9}$$

Equations 9 and 10 estimate long-run and short-run effects separately and comparing the two gives us some insight into the behaviour of farmers to change in price.

Finally, if we are interested in the differential effects of the explanatory variables that are constant over time and over units (cross section), the equation above may be written in the following manner:

$$Y_{it} = \alpha + X_{it}\beta_1 + S_i\beta_2 + Z_t\beta_3 + v_i + \varepsilon_{it} \tag{11}$$

In Equation 11 we explicitly identify explanatory variables that vary over farmers and over time (X_{it}), variables that are constant over time (S_i), and variables that vary over time (Z_t). A good example of (X_{it})would be the amount of fertilizer and labour input. An example of (S_i) is the sex or ethnic group of household head, while a classic example of (Z_t) is the price variable of major interest in the study. From Equation 11 the corresponding "between" and "within" equation can be estimated as follows:

$$\overline{Y_i} = \alpha + \overline{X_i}\beta_1 + S_i\beta_2 + \overline{Z}\beta_3 + v_i + \overline{\varepsilon_i} \tag{12}$$

$$Y_{it} - \overline{Y_i} = (X_{it} - \overline{X_i})\beta_1 + (Z_t - \overline{Z})\beta_3 + (\varepsilon_{it} - \overline{\varepsilon}_i) \tag{13}$$

In Equation 12 no estimate of β_3 is possible because $\overline{Z}$ is constant across the i observations and the intercept will be $(\alpha + \overline{Z}\beta_3)$; that is, the same time variable will be captured by the intercept. At the time Equation 13 does not give us an estimate of β_3 and the error term will capture the effect of variables that are constant over time. In other words, the error term of Equation 13 will be $(V_i + S_{ij}B_2)$

Other issues in agricultural supply response

Short-run supply responses are reflected through variable inputs; that is, there will be a change in the intensity of picking as well as the adoption of new production technology. The increase in the intensity of picking among small-scale coffee growers will be through the use of household as well as hired labour. While the former may be constant over time, the latter may vary among farmers and over a period of time. In this study modern technology includes the use of fertilizers and other chemical inputs. Both the short- and long-run supply responses may vary by farm size and it may not be easy to decompose responses of small and large-scale farms. This problem was controlled at the design and sampling stages of this survey by confining the study to small-scale peasant farmers. Besides, the fact that more than 80% of coffee production in Ethiopia comes from small-scale farmers indicates that there will not be a significant selection bias.

Supply response need not be confined to variation in labour and modern inputs, or to changes in tree removals and replanting. Response may include changes in the grade and quality of coffee. If the price differential between low and high quality coffee is substantial, then responses may not only be via changes in agricultural inputs but also by the reallocation of labour to the cleaning and washing of the existing supply. This aspect of supply response was not captured in the survey. The second best was to assemble and cross classify cross section data on the supply of different grades of coffee along with the corresponding prices. Information gathered before and after the 1992 devaluation suggests that even though there is a marked increase in the supply of both low and high grade coffee as a result of devaluation and the increased producer price of coffee, there is not a substantial difference in the rate of increase between the two grades. In other words, the possible increase in the amount of labour input is mainly for purposes of intensive picking and changes in the quality mix do not seem to be affected significantly.

VI. Issues in empirical implementation

Panel data presentation

The survey data at hand has 276 observations (small-scale farmers) for 1992, 1993 and 1994. Standard econometric techniques such as OLS, 2SIS or the Nerlovian type specifications cannot be applied to this data set, and direct short-run and long-run price elasticities cannot be estimated. As stated in the preceding section, the "error component model" is applied to the panel data. From the empirical findings we can observe whether short- and long-run supply responses to price incentives are significant. Before discussing the empirical findings, we present the survey data layout in an ANOVA form in Table 7.

Table 7: ANOVA layout panel data

Farmers	1992 coffee price Y_{11} (Low RER)*	1993 coffee price Y_{12} (Intermediate RER)*	1994 coffee price Y_{13} (High RER)*	Three-year average per farmer
1	Y_{11}	Y_{12}	Y_{13}	$\bar{Y}_{1.}$
	Y_{21}	Y_{22}	Y_{23}	$\bar{Y}_{2.}$
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
i	Y_{i1}	Y_{i2}	Y_{i3}	$\bar{Y}_{i.}$
.	.	.	.	.
.	.	.	.	.
N	Y_{N1}	Y_{N2}	Y_{N3}	$\bar{Y}_{N,}$
Mean yield per year	$\bar{Y}_{.1}$	$\bar{Y}_{.2}$	$\bar{Y}_{.3}$	$\bar{Y}_{.4}$

* See Table B2, Appendix B.

In the ANOVA layout the Y_{ij} is the response of farmer i in period j; it may also be referred to as the dependent variable. In the empirical implementation the responses refer to production or sales as well as net new planting. Production and sales are used interchangeably because small-scale coffee farmers in Ethiopia sell almost all of their produce with very little left for home consumption. A significant difference between mean yield per year $(\overline{Y_{.j}})$ indicates a long-run response; this response is already referred to as the "between effect". A significant difference within a year $(\overline{Y_{i.}})$ indicates a short run response or "within effect". The layout implies that there is a trade-off between short- and long-run responses. This approach has been applied by Madalla and Minalendran (1995) and others.

The explanatory variables included in the model are the existing amount of coffee trees, household labour, hired labour, and fertilizer and other chemical inputs; the last two are dummy variables—a value of one implying use of these inputs and a value of zero otherwise. Producer price is implicitly included as an explanatory variable. This is the "between effect" and indicates whether the price variation over 1992, 1993 and 1994 is significant in affecting a dependent variable. Real exchange rate (RER), which in this study is already defined as a ratio of tradeables to non tradeables, was included as one of the explanatory variables in the supply equation but was dropped because it was highly collinear with the producer price of coffee (r = 0.99). A significant "between effect" may also imply the positive effect of RER on coffee production (supply) and other dependent variables. A priori, all these variables are expected to have positive effect on the response or the dependent variables.

Empirical results

The model summarized in Section 5 and described in Appendix C has four components: desired production and acreage, new planting, acreage removed, and yield relationship. In the empirical implementation process, we confine ourselves to information obtained from the survey data; farmers know the number of new trees planted or old trees removed. This phenomenon is not unusual among small-scale coffee farmers in Ethiopia where land is highly fragmented and the share of each household is very small. Long-run responses seem to be manifested more by removing old trees and intensive planting of new trees within a given acreage. Thus the number of coffee trees and not acreage is used in this study. Also, instead of estimating a separate equation for removals and new planting we use one equation for net new planting, that is, new trees less removals.

We have already described the three models that are used for combining time series and cross section data. The appropriate models for the given data set are the "fixed effect" and the "random effect"; the result is discussed below.

Yield relationship

The supply or production of coffee relative to change in price and other variables is given in Table 8. Even though the sample size (N) is 274 observations, the actual number of observations— based on three-year retrospective panel data (T)—is 825. The results of both "fixed" and "random" effect models show the R^2 (between) as a measure of long-run supply response while the R^2 "within" measures the short-run supply response. Both R^2's are significant; of particular note is that the R^2 (between) illustrates the importance of devaluation and the corresponding increase in RER in enhancing long-run supply response. The short-run supply responses are also significant. The result is true for both "fixed effect" and "random effect" models. In both the models household labour, hired labour, and fertilizer have positive and significant effect on coffee production and supply. This clearly shows that farmers' respond in a rational and predictable manner in the short and long run.

Table 8: Supply response: Dependent variables—sales or production

	Model A*		Model B**	
	B	t	B	t
Existing stock	-0.003	-0.090	0.013	0.804
Household labour	21.005	3.891*	21.160	3.112*
Fertilizer	200.069	2.650*	271.081	5.582*
Other chemicals	80.989	0.893	126.230	2.052
Hired labour	392.763	3.397*	377.895	6.126*
Constant	50.238	1.105	17.724	0.456
R^2 Within	0.144		0.149	
R^2 Between	0.145		0.141	
R^2 Overall	0.143		0.145	
F(2,268)	9.070		CHI(5)=140.030	
Prob >F	0.000		Prob>CHI=0.000	
N	274		274	
NT'	825		825	
Mean	3.011		3.011	

* Fixed effect model
** Random effect model (GLS)

Net new planting

A model of net new planting is made to be a function of RER, a variable that is expected to capture the price variation of coffee and non-tradeable agricultural produce. Other explanatory variables are previous stock of trees, other perennial crops and household labour. The random effect model gave a more robust result and is presented in Table 9.

The result showed a positive and a significant relationship between RER (ratio of the producer price of coffee to that of non-tradeable agricultural produce) and net new planting, suggesting that small-scale coffee farmers expect the high domestic price of coffee to stay and a long-run response is in order. RER is the only significant variable affecting net new planting. Not only is net new planting undertaken through intensive cultivation and through uprooting old trees, but also at the expense of other perennial crops such as "chat". The "other perennial" variable is significant at 20%. Other explanatory variables were found not to be significant.

Table 9: Supply response: Dependent variable—net new planting

Variable	Model A*		Model B**	
	B	t	B	t
Real exchange rate	Dropped		0.59217.108*	
Pervious stock	0.030	2.898*	-0.00010.300*	
Household labour	-1.634	-0.258	-0.0080	-0.744
Other perennials	0.039	2.844	-0.001	-1.497
Constant	-117.817	-3.584	-2.637	-14.995*
R^2 Within	0.0038		0.0514	
R^2 Between	0.0957		0.0115	
R^2 Overall	0.0038		0.0345	
F(3,270)	0.0456		$\chi^2(4) = 297.55$	
Prob > F	0.0001		Prob > $\chi^2 = 0.0000$	
N	274		270	
NT'	550		554	
Mean	2.007		2.007	

* Fixed effect model
** Random effect model (GLS)

Conclusion

Despite a considerable effort at diversifying the export mix of the Ethiopian economy, coffee still remains the country's single most important source of foreign exchange. Like many African countries, the macroeconomic policy of the Ethiopian government between 1974 and 1991 was biased against the production of coffee and other tradeables. These biases came about as a result of inconsistent economic policies such as setting producer prices, establishing marketing boards that restricted the role of the private sector, imposing various taxes at various stages of production, marketing and export, and rationing the meager foreign exchange in favour of the state owned manufacturing and state farms. These restrictions, as well as other forms of explicit and implicit taxes, led farmers to shift production from tradeables to non-tradeables. The most serious form of implicit tax was the over-valued exchange rate, which adversely affected the production of coffee and substantially reduced foreign exchange earnings. Since October 1992, the Ethiopian currency has been devalued by 242% and the state monopoly over marketing and the export of coffee abolished.

In this study we attempted to analyse the effect of devaluation and the corresponding increase in RER in stimulating coffee supply. We developed an appropriate econometric model and identified econometric techniques for panel data so as to study the extent to which devaluation can be used to stimulate both short- and long-run coffee production and export. Some economists argue that unlike farmers in developed countries, small-scale farmers in developing countries may not respond to price incentives in a rational and predictable manner. The reason they put forward is that peasant farmers are risk averse especially in the long run. As a result of increased domestic prices, farmers may not take advantage of such incentives and thereby increase their income. Farmers are assumed to have a given income target and once this target is reached leisure time may rise. This is the so called backward bending supply curve.

Studies by Bevan et al. (1989) and Sharma (1992) show that African farmers do indeed respond to price and other incentives in a rational and predictable manner. Our results also indicate that the concept of risk aversion among Ethiopian farmers does not seem to be true; this is so in both the short and long run.

From the descriptive statistics as well as from the econometric findings it was noted that farmers do indeed respond positively to devaluation via increase in RER. Both the short- and long-run supply responses were significant. The structure of production was such that both human and material resources at the disposal of farmers were diverted to the production of coffee; the quantity produced and sold was considerable and as a result more foreign exchange was acquired and farmers' incomes increased considerably.

The responses were manifested through intensity in the picking of coffee, greater use of fertilizer, more use of household and hired labour, uprooting of old trees and planting new ones sometimes at the expense of other perennial and annual crops. The parallel market and the resultant coffee smuggling have been reduced. In general, the injustice done to farmers because of inappropriate macroeconomic policies seems to be in the process of being alleviated. The RER may thus be recognized as one of the major policy variables for restructuring the economy. Our results show that correcting the exchange rate misalignment should the major source of foreign exchange earning and constitutes a high percentage of a countryís GDP.

Despite the satisfactory achievement, continued reliance on coffee as the major source of foreign exchange earnings may not be appropriate in the long run. There are other issues that policy makers must consider with the view of diversifying sources of foreign exchange earnings while at the same time enhancing the production and supply of coffee. Issues such as monetary, fiscal and commercial policies must be addressed and made to be consistent with the process of RER realignment. If these and related issues are not simultaneously addressed, the observed increase in foreign exchange and the positive supply response that comes about as a result of devaluation may not be sustained.

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Appendix A

Real Exchange Rate and Agricultural Supply Response in Ethiopia: The Case of Perennial Crop

Questionnaire

1. Household data Age or Number

Employment	A = Expected	B = 1st year	C = two years	D = three years
Head				
Spouse				
Children > 15				
Children 10 - 14				
Children < 10				
Relatives > 15				
Relatives 10 - 14				
Relatives < 10				
Employees				

2. Crops cultivated

Crop Area	A	B	C	D
Coffee				
Other perennial				
Annual crops				
Total area				

3. Age of coffee tree (current)

Age	No	Yield
< 1		
1 - 2		
3 - 4		
5 - 6		
7 - 8		
> 8		

4. Removal, replanting and new coffee tree

	A	B	C	D
Trees uprooted				

Trees replanted	
New trees (acreage)	

5. Other perennial and annuals

Crop type	A		B		C		D	
	Area	Yield	Area	Yield	Area	Yield	Area	Yield
Cereals								
Pulses								
Oilseeds								
Others								

6. Use of modern inputs and labour

	A		B		C		D	
	Coffee	Other	Coffee	Other	Coffee	Other	Coffee	Other
Fertilizer								
Insecticide								
Herbicide								
Tractor (rent)								
No. of workers								

7. Wealth ownership

	A	B	C	D
Cattle				
Sheep and goat				
HMCD				
Other (specify)				

Other sources of income (yearly estimate)

Appendix B: Exchange rates and tradeable and non-tradeable prices

Table B1: Official and parallel market exchange rate and exchange premium (quarterly data)

		Official (A)	Parallel (B)	Premium B/A
1990	1	2.07	7.00	3.38
	2	2.07	7.00	3.38
	3	2.07	7.00	3.38
	4	2.07	7.00	3.38
1991	1	2.07	7.50	3.62
	2	2.07	7.50	3.62
	3	2.07	7.50	3.62
	4	2.07	7.50	3.62
1992	1	2.07	7.50	3.62
	2	2.07	7.80	3.77
	3	2.07	7.80	3.77
	4*	5.00	7.80	1.56
1993	1	5.00	7.50	1.50
	2	5.02	7.58	1.51
	3	5.48	7.35	1.34
	4	5.51	7.25	1.32
1994	1	5.12	7.35	1.24
	2	6.25	7.45	1.19
	3	6.19	7.50	1.21
	4	6.28	7.55	1.20

Table B2: Price of coffee (tradeable) and cereals (non-tradeable) and real exchange rate (quarterly data)

		Price of Coffee (A)	Price of cereals (B)[1]	Real exchange rate (B/A)
1990	1		554	
	2		532	
	3		570	
	4		597	
1991	1	2,571	649	3.96
	2	2,610	821	3.15
	3	2,498	940	2.65
	4	2,549	912	2.79
1992	1	2,445	856	2.86
	2	2,362	874	2.70
	3	2,308	920	2.50
	4	4,666	924	5.05
1993	1	5,720	849	6.74
	2	5,680	848	6.70
	3	8,490	833	10.19
	4	7,649	814	9.40
1994	1	7,181	783	9.17
	2			
	3			
	4			

[1] Most cereals produced in Ethiopia are domestically consumed. Official statistics show that exchange rate earning from cereals is less than 1%.

Appendix C: Long-run supply response model

A more detailed presentation of a Nerlovian type econometric model that is appropriate for the study of a short-run and long-run supply response is given below. Like other econometric models, the empirical implementation will not be an easy exercise. Several assumptions and modifications have to be made so as to make the estimation exercise manageable. The estimation process is similar to those of Nerlove (1983) and related studies, and requires time series data of a long duration.

1. Desired production and acreage

The major determinants of desired production are the expected profit of the tree crop and the profitability of alternative uses of the land. On the other hand, expected profitability is a function of prices and costs. Let the long-run rate of profitability per unit output be (π_t^*); this is calculated from the equilibrium price that will cover cost plus normal profit. Farmers are also expected to form conditional long-run expectations about likely earnings from expected normal yields Y_t^* and previous period level of bearing acreage (A_{t-1}). From the yield and acreage expectations farmers will also form conditional profit (π_t^e). In the end farmers will adjust the level of average production by relating equilibrium and conditional profits. The model for this argument can be expressed as:

$$Q_t^* = Q_{t-1}^* + b_{11}(\pi_t^e - \pi_t^*) + b_{12}(\pi_{At}^e - \pi_{At}^*) + U_{1t} \qquad (1)$$

Where Q_t^*	=	desired production for year t
$Q_{t-1}^* = Y_t^* A_{t-1}$	=	expected average production with actual level of acreage of A
π_t^e	=	expected long-run profitability per unit with production of Q*
π_t^*	=	normal long-run (equilibrium) profitability for the commodity under consideration
$\pi_{At'}^e \pi_{At}^*$	=	same as π_t^e and π_t^* but for other commodities
U_{lt}	=	disturbance term

One would, a priori, expect the signs of b_{11} and b_{12} to be positive and negative, respectively. This is because positive deviation of conditional probability expectation from the equilibrium would lead to desired production greater than the normal. This is for the crop under consideration. The opposite would true be for other commodities.

We also need an equation that explains changes in the quantity of bearing that producers desire to hold. This may be derived from Equation 1 and is given by

$$A_t^* = \frac{Y_{t-1}^*}{Y_t^*} + \frac{b_{11}}{Y_t^*}(\pi_t^e - \pi_t^*) + \frac{b_{12}}{Y_t^e}(\pi_{At}^e - \pi_{At}^*) + \frac{U_{lt}}{Y_t^e} \tag{2}$$

Equation 2 is cumbersome for empirical implementation and the following linear equation is adopted by French et al. (1985):

$$A_t^* = A_{t-1} + b_{31}(\pi_t^e - \pi_t^*) + b_{32}(\pi_{At}^e - \pi_{At}^*) + b_{33}\Delta Y_t^* + U_{31} \tag{3}$$

Where $\Delta Y_t^* = Y_t^e - Y^e - t - 1$

2. Desired new planting

For a given desired level of acreage, desired new planting is given by

$$N_t^* = A_{t-k}^* + A_{t-1} + R_{kt}^e - N_{kt-1} \tag{4}$$

Where	N_t^*	=	acreage of new planting desired by growers in year t
	k	=	time interval between initial planting and first bearing
	R_{kt}^e	=	total amount of acreage expected to be removed during the next k years
	$N_{kt-1} = \sum_{i=1}^{k} N_{t-i}$	=	total acreage planted after year t-k-1

Actual planting can be related with the observed planting as follows

$$N_t = \alpha N_t^* + \beta(1-\alpha)N_{t-1} + e_t \tag{5}$$

Where α and β are coefficients of adjustment .

Equation 5 may now be expressed in terms of changes in quantity of bearing (A_t^* in Equation 3). The final form will be

$$N_t = b_{61}(\pi_t^e - \pi_t^*) + b_{62}(\pi_{At}^e - \pi_{At}^*) + b_{63}\Delta Y_t^e + b_{64}A_{t-1}^0 + b_{65}N_{kt-1} + b_{66}A_{t-1} + U_{6t}$$

3. Acreage removed

Acreage removed may be affected by declining productivity, institutional and physical factors, short-term profit expectations, and other random factors. The equation may thus be expressed as:

$$R_t = b_{70} + b_{71}A_t^0 + b_{72}A_t^0(\pi_t^e - \pi_t^*) + b_{73}A_t^0(\pi_{At}^e - \pi_{At}^*) + b_{74}Z_t + b_{75}A_t + U_{7t}$$

Where R_t = acreage removed at the end of year t

A_t^0 = acreage over a particular age in year t

π_t^e = short run profit expectations for year t+1

π_{At}^e = same as π_t^e but for alternative products

Z_t = variables accounting for institutional or physical factors

A_t = bearing acreage in year t

U_{7t} = disturbance term

4. Yield relationship

We have already stated that yield of perennial crops varies with age of bearing trees, and with technology, weather and biological factors; current yields may thus be expressed as:

$$Y_t = \sum_{i=k}^{H} a_i A_{it} + b_{81}T + V_{8t}$$

Where A_{it} = acreage of the ith age in year t

k = initial bearing age

H = estimated maximum age of plants

T	=	technology variable
V_{8t}	=	disturbance term

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