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PRICE EXPECTATIONS IN PERENNIAL CROP SUPPLY MODELS

by

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ABSTRACT

In the analysis of investment and production decisions for perennial crops, expectations play a critical role. This thesis studied three hypotheses about price expectations and reviewed five supply response models for perennial crops. An empirical model for the apple industry was developed to test alternative representations of expected prices. The naive and adaptive expectation model performed well with national data, whereas moving averages of price and the adaptive expectations model performed better with Washington data.

To improve estimates of supply response for perennial crops, better data are needed to describe new plantings, removals, the age distribution of trees, production costs, and climatic conditions. Rapid technological change in the U.S. apple industry may cause producers to revise the way they form expected prices, encouraging them to use more historical information and paying more attention to projections of future demand. Rational expectations perspectives may become increasingly relevant.

CHAPTER 1

INTRODUCTION

In the analysis of investment and production decisions for perennial crops, expectations play a critical role. Investment occurs at the beginning of the production period; this fixed capital investment is irreversible with zero salvage value. Revenues typically begin only after some gestation period and continue through the remaining life of the tree. Since fixed costs are a prominent part of total costs, output adjustment after investment is minimal even if realized prices are different from expected prices. The focus of this thesis is on the role of price expectations in perennial crop production. Expected price is a key element in perennial supply response analysis. The long planning horizon for perennial crops means that growers have substantial uncertainty about future prices. Planting decisions must be made much more carefully than those for annual crops.

Organization of the Study

The research has several objectives. Different price expectation hypotheses are compared in Chapter 2. Previous models on supply response of perennial crops are reviewed in Chapter 3. This review emphasizes the elements that make research on perennial crops different from that for annual crops and compares the price expectations hypotheses of the models. In chapter 4, supply models are developed for the apple industry using different expected price formulations. Chapter 5 summarizes the conclusions and makes suggestions for further research.

CHAPTER 2

THEORIES ABOUT PRICE EXPECTATIONS

Expectations are influenced by actual events, and it is important to understand what information is used to form expectations and how it is used to estimate future values. Models Models of expectation formation can be characterized as methods of arriving at certainty equivalents for uncertain future values. The certainty equivalent expectations held by the representative firm are not necessarily observable. The problem in supply analysis is to construct an empirically useful hypothesis which relates these expectations to observable variables. This chapter reviews three types of models: pre-Nerlove models, Nerlove's adaptive expectations model, and Muth's rational expectations model.

Pre-Nerlove Models

The earliest and simplest explanation of agricultural price expectations, that production is influenced solely by the most recent season's price, is embodied in the cobweb model (Ezekiel, 1938). The cobweb model usually has been used to illustrate market situations where changes in the quantities available for the market can occur only at particular times. It is expressed as

$$Q_t = f(P_{t-1}) \qquad (2.1)$$

where Q_t is the production in year t, and P_{t-1} is the price in year t-1.

A cobweb is stable or unstable depending on the relative elasticities of the demand and supply curves. The market equilibrium will be stable when demand is more elastic than supply. Otherwise, quantity and price will oscillate around their equilibrium levels.

The cobweb model has been criticized on two grounds. First, such models have not forecast events accurately. Second, the view of price expectation behavior is theoretically unsatisfying because it neglects information that might be contained in other past data.

A more sophisticated approach to expectations was suggested by Richard Goodwin. In order to allow for a "learning" process on the part of producers, he formulated expected price (p_t^e) as a function of the price last period plus (or minus) some proportion of the most recent change in actual price:

$$p_t^e = p_{t-1} + q\,(p_{t-1} - p_{t-2}) \qquad (2.2)$$

This formulation of expectations represents the extrapolative hypothesis. The discrepancy between the desired and the expected values are not a concern in this model. Expectations are determined by the two most recent past periods and neglect information contained in earlier experience.

Nerlove's Adaptive Expectations Model

The work of Marc Nerlove (1958) started an econometric tradition in estimating agricultural supply relations. It has greater intuitive appeal than the pre-Nerlovian models because it allows people to revise their notion of "normal" price in proportion to the difference between current price and their previous idea of a "normal" price.

The Nerlovian model appears less naive than the pre-Nerlove models because it allows for adjustment of expectations. Adaptive expectations processes do not contradict the long-run equilibrium. Expected price is the 'normal' price expected to prevail in all future periods.

Expected price, P_t^e, can be explained by last period's expected normal price plus or minus an adjustment, expressed as a proportion, ß, of the difference between last period's expected "normal" price and the actual price.

$$P_t^e = P_{t-1}^e + \beta(P_{t-1} - P_{t-1}^e) \qquad (2.3)$$

where P_t^e and P_{t-1}^e are the expected prices of the current and previous periods, respectively, P_{t-1} represents last period's price, and ß is the adjustment coefficient. If ß is zero, actual prices are totally divorced from expectations. A value of one implies the cobweb model, in which expected prices are identical with last year's price.

A first order difference equation can be solved for P_t^e, yielding equation (2.4):

$$p_t^e = \sum_{i=1}^{\infty}\beta(1-\beta)^{i-1}p_{t-i} \qquad (2.4)$$

Expected price is represented as a moving average of past prices, with the weights declining over time. The whole time series of prices governs expectations about "normal " price levels.

To introduce expectations into a supply-model, quantity supplied (Q) is expressed as a function of expected price (p_t^e):

$$Q = a_0 + a_1 P_t^e + u_t \qquad (2.5)$$

Iterative procedures can be used to estimate output, Q, by substituting (2.4) into (2.5):

$$Q_t = a_0 + a_1 \sum_{i=1}^{\infty}\beta(1-\beta)^{i-1}p_{t-i} + u_t \qquad (2.6)$$

A non-iterative procedure, using equations (2.3) and (2.5), results in a regression equation of the following form:

$$Q_t = \pi_0 + \pi_1 P_{t-1} + \pi_2 Q_{t-1} + v_t \qquad (2.7)$$

where $\pi_0 = a_0 \beta$

$\pi_1 = a_1 \beta$

$\pi_2 = (1-\beta)$.

Equation (2.7) permits estimation based on only two lag terms.

The major criticism of the adaptive model is that expectations of prices should not be represented by a purely stochastic scheme. Without a general theory of expectations, it is dangerous for policy advice to be made contingent on what economists think the public believes. The estimates of expectations therefore are biased.

However, Nerlove claimed that rational farmers should not respond to the best forecast of price (a long run equilibrium position determined on the basis of static optimization). Entrepreneurs might increase profits if they improve the accuracy of their forecasts, but probably not much more than profits earned from responding to "normal" expected values. In other words, extra potential profits are not usually worth the added expense of significant improvements in accuracy. It is more useful to predict "normal" levels of a future value than to forecast its value for a particular time period.

Muth's Rational Expectations Model

John F Muth advanced the rational expectation hypothesis in 1960. In this model, expected values are essentially the same as the values predicted by economic theory. Producers behave as if they possess a model of the market. If producers maximize profits, Muth reasoned that they do not err greatly in making forecasts, or at least do not err more than the best model available to predict behavior. If expectations were not rational, then a small group of individuals, whose expectations are better than those of the rest, would gradually drive others out of business. Those who do not follow rational expectations do not survive; those who survive must try to maximize profits.

The subjective probability distribution of expected values then coincides with the true objective probability distributions. One of the implications of rational expectations is that expected values change only when the conditional probability of the distribution governing the variable changes. Fixed expectations models, such as Nerlove's do not allow expectations to change when the structure of the system changes.

Since expectations depend on the entire economic model, it is difficult to explain this hypothesis outside of a particular context. In order to compare rational expectations with other models, the rational expectations hypothesis is applied to a simple cobweb system. Consider a simple model of a market containing a supply equation,

$$Q_t^S = a_0 + a_1 p_t^e + u_t \qquad (2.8\ a)$$

where Q_t^S is the quantity supplied, p_t^e is the expected price, and u_t is a random residual which reflects variations due to weather, technology, or other exogenous variables.

The model also contains a demand equation,

$$Q_t^D = b_0 + b_1 p_t \qquad (2.8\ b)$$

where Q_t^D is the quantity of demand, and p_t is the current price.

Setting $u_t = 0$, $p_t^e = p_t = p_t^*$ and $q_t = q_t^*$, the equilibrium price, p^*, and quantity, q^*, are obtained by solving (2.8a) and (2.8b),

$$p^* = \frac{b_0 - a_0}{a_1 - b_1} \qquad (2.9a)$$

$$q^* = \frac{a_1 b_0 - a_0 b_1}{a_1 - b_1} \qquad (2.9b)$$

Suppose the disturbance term u_t can be written as weighted sum of independently and normally distributed random variables ε with zero mean and common variance σ^2:

$$u_t = \sum_{i=0}^{\infty} w_i \varepsilon_{t-i} \qquad (2.10)$$

By assuming $Q^S = Q^D$, the following relationship can be obtained from (2.8a) and (2.8b):

$$a_0 + a_1 p_t^e + u_t = b_0 + b_1 p_t \qquad (2.11)$$

i.e. $$b_0 - a_0 = a_1 p_t^e - b_1 p_t + u_t \qquad (2.12)$$

Substituting (2.9a) and (2.10) into (2.12), gives

$$p_t - p^* = \frac{a_1}{b_1}(p_t^e - p^*) + \frac{1}{b_1} \times \sum_{i=0}^{\infty} w_i \varepsilon_{t-i} \qquad (2.13)$$

$\bar{p}_t = p_t - p^*$ and $\bar{p}_t^e = p_t^e - p^*$. Then equation (2.13) can be rewritten:

$$\bar{p}_t = \frac{a_1}{b1} \times \bar{p}_t^e + \frac{1}{b_1} \times \sum_{i=0}^{\infty} w_i \varepsilon_{t-i} \qquad (2.14)$$

The expected value of equation (2.14) is written as

$$E(\bar{p}_t) = \frac{a_1}{b_1} E(\overline{p_t^e}) + \frac{1}{b_1} E(\sum_{i=0}^{\infty} w_i \varepsilon_{t-i}) \qquad (2.15)$$

If expectations are rational, average expected price, $p_t^{e'}$ must equal the mean value of the actual price, p_t'.

Since $E(\varepsilon_t' | \varepsilon_{t-1}, \varepsilon_{t-2}, \ldots) = E(\varepsilon_t) = 0$,by assumption, it follows that

$$\bar{p}_t^e = \frac{a_1}{b_1} \times \bar{p}_t^e + \frac{1}{b_1} \sum_{i=1}^{\infty} w_i \varepsilon_{t-i} \qquad (2.16)$$

So $$\bar{p}_t^e = \frac{1}{b_1 - a_1} \times \sum_{i=1}^{\infty} w_i \varepsilon_{t-i} \qquad (2.17)$$

i.e. the expected price for period t is a weighted sum of past (unobservable) random shocks.

Substituting (2.17) into (2.14) yields

$$\bar{p}_t = \frac{a_1}{b1} \times \frac{1}{b_1 - a_1} \times \sum_{i=1}^{\infty} w_i \varepsilon_{t-i} + \frac{1}{b_1} \times \sum_{i=1}^{\infty} w_i \varepsilon_{t-i} + \frac{w_0}{b_1},$$

$$\bar{p}_t = \frac{w_0}{b_1} + \frac{1}{b_1 - a_1} \sum_{i=1}^{\infty} w_i \varepsilon_{t-i} \qquad (2.18)$$

The random shock, $\varepsilon_{t,}$ has a permanent and a transitory effect on u_t. A raction of this shock, ß, permanently affects u_t.

$$u_t = \varepsilon_t + \beta \left(\sum_{i=1}^{\infty} {}_i\varepsilon_{t-i} \right)$$

$$w_0 = 1 \qquad (2.19)$$

$$w_i = \beta, \; i = 1,2,....$$

From (2.18) and (2.19) we have

$$\bar{p}_t = \frac{1}{b_1} \varepsilon_t + \frac{\beta}{b_1 - a_1} \left(\sum_{i=1}^{\infty} w_i \varepsilon_{t-i} \right) \qquad (2.20)$$

Hence,

$$\varepsilon_t = b_1\bar{p}_t - \frac{b_1\beta}{b_1 - a_1}\left(\sum_{i=1}^{\infty}\varepsilon_{t-i}\right) \tag{2.21}$$

Taking expectations of the above equation gives

$$E(\varepsilon_t) = b_1 E(\bar{p}_t) - \frac{b_1\beta}{b_1 - a_1} E\left(\sum_{i=1}^{\infty} w_i \varepsilon_{t-i}\right) \tag{2.22}$$

Because $E(\varepsilon_t) = 0$ and $E(\bar{p}_t) = \bar{p}_t^e$,

$$\bar{p}_t^e = \frac{\beta}{b_1 - a_1}\left(\sum_{i=1}^{\infty} w_i \varepsilon_{t-i}\right) \tag{2.23}$$

Substituting (2.23) into equation (2.20),

$$\bar{p}_t = \frac{1}{b_1} \times \varepsilon_t + \bar{p}_t^e \tag{2.24}$$

It follows that

$$\varepsilon_{t-i} = b_1 (\bar{p}_{t-i} - \bar{p}_t^e) \tag{2.25}$$

Substituting (2.25) in to (2.23) and lagging one period,

$$\bar{p}^{e}_{t-1} = \frac{b_1\beta}{b_1-a_1} \times \sum_{i=1}^{\infty}(\bar{p}_{t-i-1} - \bar{p}_{t-i-1}{}^{e})$$

$$= \frac{b_1\beta}{b_1-a_1} \times \sum_{i=1}^{\infty}(\bar{p}_{t-i} - p_{t-i}{}^{e}) - \frac{b_1\beta}{b_1-a_1} \times (\bar{p}_{t-1} - p_{t-1}{}^{e})$$

$$= \bar{p}^{e}_{t} - \frac{b_1\beta}{b_1-a_1} \times (\bar{p}_{t-1} - \bar{p}_{t-1}{}^{e}) \qquad (2.26)$$

Since the equilibrium price cancels out when a difference of primed variables is taken, equation (2.26) may be rewritten in the form

$$p_t{}^{e} - p_{t-1}{}^{e} = m(p_{t-1} - p_{t-1}{}^{e}) \qquad (2.27)$$

where $m = b_1\beta/(b_1-a_1)$. Since $b_1 < 0$, $a_1 > 0$, and $0 < \beta <= 1$, $0 < m <$ or $= 1$. Equation (2.27) generates the adaptive expectations model. The rational expectations model is thus consistent with the adaptive expectations model even though the two models were derived from different hypotheses. In this case, adaptive expectations can be considered as an approach to forecast rational price based on the information available up to the time the forecast is made.

Muth has shown that adaptive expectations are optimal if the time series to be forecast results from two kinds of random components, one lasting a single time period -- $b_1/(b_1-a_1)$, and the other lasting through all subsequent time periods (β). Muth calls these the transitory and permanent components of the time series.

In order to compare with the Nerlove model, quantity supplied can be expressed by combining equations (2.27) and (2.8), and using β^r to distinguish from the β in the adaptive expectations model:

$$Q_t = \pi_0' + \pi_1' P_{t-1} + \pi_2' Q_{t-1} + v_t \qquad (2.28)$$

where $\pi_0' = a_0 b_1 \beta^r/(b_1-a_1)$

$\pi_1' = a_1 b_1 \beta^r/(b_1-a_1)$

$\pi_2' = 1-b_1 \beta^r/(b_1-a_1)$

Compared to the Nerlove model, the Muth model contains more parameters (a_0, a_1, b_1, β^r), even though the supply function looks the same. These parameters are underidentified and can not be recovered from the estimated coefficients in equation (2.28). The situation becomes more complicated when other variables, such as income or a random shock, are introduced in the demand equation. Rational expectations in such cases will depend on other variables in addition to past prices.

Several criticisms have been directed toward the rational expectations hypothesis. First, real situations are more complicated than economic theory, and noneconomic influences on markets may cause random disturbance to be non-normally distributed. Individual probability beliefs may not coincide with those of others or with the true objective probability distributions of economic variables.

Second, the rational expectations hypothesis does not include learning and adaptive behavior. Individuals calculate the expected values of key variables on the basis of the true probability distributions for the system. However, no description is given of how individuals actually find or learn about the probability distributions. These "learning processes" may not lead to a system that follows Muth's hypothesis.

Finally, Nerlove argued that the rational expectations model is not a dynamic model but a comparative static one. One implication of Muth's definition is that the agent's expectation about a variable changes only when the conditional probability distribution changes. Otherwise, expectations are stationary. A dynamic theory would base expectations on all information available. But such a theory would not, in general, involve the notion of a long run equilibrium towards which adjustment is being made, nor simple forms of stationary expectations.

In this case, new expectations formulations are needed, such as a simple average of past prices. When production and prices fluctuate substantially over time, producers may form their expectations in a simple fashion, considering average profits during several recent years.

Conclusion

The chapter has reviewed several plausible hypotheses about the way that price expectations are formed. The different approaches to price expectations are not mutually exclusive. When the coefficient of price expectation, β, is equal to one, expected prices are identical with last year's price. Hence, adaptive expectations will be consistent with naive price expectations. If the economic structure of a model remains unchanged, adaptive expectations will reach the same equilibrium as the rational expectations model; only the path to equilibrium differs.

But adaptive expectations can not be representative when the future economic structure is predicted to change dramatically from present and past structures. Producers are concerned about how price will change in the future and historical information will have little value. Changed expectations are better represented by rational expectations in these circumstances. However, the rational expectations model depends on the structure of the entire economic system and requires more information. Finally, it is possible that none of the above models is directly applicable, and other representations need to be developed.

CHAPTER 3

A REVIEW OF MODELS OF PERENNIAL CROP SUPPLY

This chapter reviews models of perennial crop supply developed by Bateman, Wicken's and Greenfield, Hartley, Nerlove and Peters, French, and Baritelle and Price.

Bateman's Model

Bateman (1965) was the first to apply Nerlove's model to perennial crop supply estimation. He studied cocoa in Ghana. In the model, the farmer is assumed to maximize the net present value of his investment. Bateman contended that expected prices were the most important influence on planting decisions. Thus, planted acreage was represented as a function of the discounted prices of cocoa and its substitute, coffee:

$$A_t = a_0 + a_1 \bar{p}_t + a_2 \bar{c}_t + u_t \qquad (3.1)$$

where A_t is the number of acres planted in year t, $\bar{p}_t$ is the mean value of discounted expected future prices of coffee, and $\bar{c}_t$ is the mean value of discounted expected future prices of cocoa. The model assumes that the expected yield and costs are relatively stable (or else change slowly in response to price changes), thus allowing omission of other variables.

Price expectations are formed in a Nerlovian pattern:

$$\bar{p}_t - \bar{p}_{t-1} = \beta(p_t - \bar{p}_{t-1}) \qquad (3.2a)$$

$$\bar{c}_t - \bar{c}_{t-1} = \gamma(c_t - \bar{c}_{t-1}) \qquad (3.2b)$$

where p_t is the real producer price of cocoa in year t and c_t is the real producer price of coffee in year t.

Solving for $\bar{p}_t$ and $\bar{c}_t$ in (3. 2) and substituting in (3.1) gives the following equation:

$$A_t = a_0\beta + a_1\beta P_t + a_2\beta C_t + (1 - \beta)A_{t-1} + v_t \quad (3.3)$$

Lacking data for newly planted acreage, Bateman respecified the model in terms of output. Output is the result of prior plantings for a number of years, rainfall, and prices at harvesting time. The supply function is represented as follows:

$$Q_t = b_1 \sum_{i=k}^{s-1} (A_{t-i}) + b_2 \sum_{i=s}^{\infty} (A_{t-i}) + cR_{t-1} + dH_{t-1} + eP_t \qquad (3.4)$$

where Q_t is the amount of cocoa harvested in year t, P_t is the real producer price. k is the age at which cocoa trees first begin to bear, s is the year in which a further increase in yield occurs, H_{t-1} is a humidity variable (humidity adversely affects yield through encouragement of black pod and other fungal diseases), and R_{t-1} is the amount of rainfall during the bean's formative stages.

Equation (3.4) was transformed into a first order differential equation:

$$\Delta Q_t = b_1 A_{t-k} + (b_2 - b_1) A_{t-s} + c(\Delta R_{t-1}) + d(\Delta H_{t-1}) + e(\Delta P_t) \qquad (3.5)$$

Combining equation (3.5) with equation (3.3) shows that output is a function of lagged own and substitute prices, lagged weather, and humidity.

$$\Delta Q_t = b_1 a_0 \beta + b_1 a_1 \beta P_{t-k} + (b_2 - b_1) a_1 \beta P_{t-s} + b_1 a_2 \beta C_{t-k}$$

$$+ (b_2 - b_1) a_2 \beta C_{t-s} + c(\Delta R_{t-1}) + d(\Delta H_{t-1}) + e(\Delta P_t)$$

$$+ (1-\beta)(Q_{t-1} - c\Delta R_{t-2} - d\Delta H_{t-2} - e\Delta P_{t-1}) + w_t \qquad (3.6)$$

where $w_t = b_1 v_{t-k} + (b_2 - b_1) v_{t-s}$

The model was applied to five cocoa growing regions in Ghana for the time period, 1946 to 1962. In every region, the coefficients for Q_{t-1}, R_{t-2}, H_{t-2}, ΔP_{t-1}, and ΔP_t were insignificant and very close to zero. A zero value for the lagged dependent variable coefficient means that the beta coefficient in the Nerlovian model is approximately one, implying that expected price is determined largely by the prevailing price. A comparison of the regional results suggested that output response was related positively to soil quality and inversely to the age of the tree population.

Wickens and Greenfield's (WG) Model

Wickens and Greenfield (1973) pointed out that Nerlove's model does not apply directly to tree crops. They modified the Nerlovian adaptive expectations model by constructing a distributed lag model with three structural equations to represent the unique characteristics of perennial crops. The model has separate equations to represent investment, harvesting and a vintage production function.

The vintage production function represents potential production as the product of past plantings and average yield, summed over time:

$$pq_t = \sum_{i=0}^{n} \delta(i,t) I_{t-i} \qquad (3.7)$$

where pq_t is potential production in year t, I_{t-i} is the number of trees planted i years ago, and $\delta(i,t)$ is the average yield in time t of trees of age i.

The investment equation is a function of discounted net marginal revenues (V), evaluated at expected future prices and costs. Investment increases until the marginal cost of investing in one more tree equals the expected discounted net revenue obtained from future production.

If planting density is constant, net investment can be formulated as the net change in acreage, excluding uprooted or abandoned acreage. Assuming adaptive expectations, expected revenue can be approximated by a distributed lag of prices. The investment function was postulated as

$$I_t = a_0 + a_1 I_{t-1} + \beta p_t \qquad (3.8)$$

where I_t is investment and p_t is the price in period t.

The harvest function provides an estimate of short-run supply. Actual production is related to maximum potential production and a weighted average of recent prices, represented by a short distributed lag of prices. An additional term is included to reflect the biennial production cycle ($\overline{\gamma} < 0$).

$$q_t = \gamma_0 + \gamma_1 q p_t + \sum_{i=0}^{m} \gamma_{i+2} p_{t-i} + \bar{\gamma} \Delta q_{t-1} \qquad (3.9)$$

where q_t is output, and p_{t-i} is the price lagged i years.

Because of data limitations, the full set of structural equations could not be estimated. Instead, the model was estimated using the following reduced form,

$$q_t = \sum_{i=0}^{n} \beta_i p_{t-i} + (\bar{\gamma} + \alpha_1) q_{t-1} - \bar{\gamma} \alpha_1 q_{t-2} + \text{constant} \qquad (3.10)$$

The price coefficients depend on yield and the short-run harvesting decision, whereas the lagged values of output are influenced by the investment function and the biennial cycle.

The model was estimated for Brazilian coffee. The distributed lag function shows a decreasing tendency in the first three years, followed by increasing response in the next four years and another decreasing trend after that. The sum of the absolute values of the coefficients is highly significant. However, the structural parameters are underidentified and elasticities of the individual parameters were unknown.

Hartley, Nerlove and Peters (HNP) Model

The reduced-form supply function developed by Wickens and Greenfield for Brazilian coffee does not capture all aspects of supply response for perennial crops. Hartley, Nerlove and Peters' Model (HNP's Model) expanded the WG model to include uprooting and replanting decisions. The model was used to estimate rubber supply response in Sri Lanka. They claimed that new plantings and replantings are qualitatively different investment decisions. Separate replanting and new planting equations were contained in the HNP model. In comparison, the WG model had only a single investment function. The available data for age distribution, stock of trees, new plantings and replantings permitted estimation of each equation in the structural model.

The model assumes that growers compare current prices with long term expectations of prices in order to decide whether to uproot and replant a given stand. The higher the current price relative to expected normal price levels, the less would be replantings; the higher the level of expected normal prices, the more it would pay to replant. Replanting was thus expressed as a function of expected price and the difference between actual and expected price:

$$R_t = a_0 + a_1[p_t - p_t^e] + a_2 p_t^e$$

$$+ a_3 w_t + a_4 s_t + a_5 AGE_t + u_t \qquad (3.11)$$

where R_t is replanted acreage, p_t is actual price, p_t^e is the expected price, w_t is the wage rate, and s_t is the per acre subsidy given to replantings in year t. AGE_t is a variable reflecting the empirical age distribution.

The adaptive expectations formulation performed best in the model and it was adopted for the determination of "expected normal price". The coefficient of expectations, β, used to calculate p_t^e, was determined by iterative methods. A value of 0.15 for β provided the best fit. The short run price elasticity was negative but statistically insignificant; the price elasticity at the mean values of R_t, p_t and p_t^e was only -0.005. The long-run price elasticity of supply with respect to p_t^e was highly significant and positive, with a mean value of +1.74. The subsidy was also highly significant and may have been responsible for the finding of a negative short run response.

New planting was difficult to estimate because virtually none occurred during the period under study. New planting depends on the same variables as replanting, except that the entire age distribution of the stock, not just the number of old trees, is relevant to the new planting decision. Moreover, because rubber output is not forgone (only the output of other crops is displaced), current prices are not likely to matter much for new planting; longer-term expectations of prices play a more important role. The new planting equation is:

$$N_t = g_0 + g_1 Q_t^* + g_2 p_t^e + g_3 w_t + e_t \qquad (3.12)$$

where Q_t^* is the potential output given by age-yield profile.

The results for the estimation of the new planting equation showed that only the constant term was significant. Prices and wages both had unexpected signs.

The HNP model goes one step beyond the WG model in that replanting and removal behaviors are considered explicitly. A focus on new planting was considered inappropriate for a mature industry, such as rubber in Sri Lanka. Here, most response to price takes the form of uprooting and replanting of existing stands. This analysis was facilitated by the availability of detailed time series data on new plantings, replantings and uprootings, and thus may not be widely applicable to other perennial crops.

French Models

The early work of French is on "The Lemon Cycle" (French and Bressler1962). The conditions essential to cobweb behavior were hypothesized to exist in the California lemon industry. Nerlove's adaptive expectations and Muth's rational expectations model did not seem directly applicable to this case. Producers were well aware of the substantial year-to-year fluctuations in supplies and prices, and were thought to formulate their long-term expectations on the basis of average profits during several recent years. Periods of various lengths were tested in the empirical analysis. New plantings were explained best by five-year averages of net returns per acre.

French and Matthews introduced a more complete model for asparagus supply response (the FM model) in 1971. The FM model assumes that the producer takes account of the impact of his own production on total output and profits. The rate of adjustment in response to a given profit disequilibrium is determined by the producers.

Two functions explained quantity produced and bearing acreage. Producers are assumed to have in mind an equilibrium rate of profitability (π_t^*). Each year, producers form conditional long-run expectations about average price (π_t^e) with expected normal yields and the current bearing acreage. Given their conditional and equilibrium profit expectations, producers adjust production to maximize long-run profitability. The adjustment process may be expressed as

$$Q_t^* = Q_{t-1}^e + a_1(\pi_t^e - \pi_t^*) + a_2(\pi_{At}^e - \pi_{At}^*) + u_t \qquad (3.13)$$

where Q_t^* is desired output, Q_t^e is expected average output, π_t^e and π_{At}^e are expected long run profits for the crops and its alternative, and π_t^* and π_{At}^* are normal long run profits for the crop and its alternative.

$$Q_t^* = Y^e * A_t \qquad (3.14)$$

where Y^e is expected normal yield, A_t is total bearing acreage.

Substituting (3.13) into (3.14) and rearranging terms yields

$$A_t = \{ A_{t-1} + c_1(\pi_t^e - \pi_t^*) + c_2(\pi_{At}^e - \pi_{At}^*) \}/Y_t^e \qquad (3.15)$$

A more convenient formulation which is linear and similar to (3.15) for a small change in Y_t^e was adopted for estimation purposes:

$$A_t = A_{t-1} + c_1(\pi_t^e - \pi_t^*) + c_2(\pi_{At}^e - \pi_{At}^*)$$
$$+ c_3 \Delta Y_t^e + w_t \qquad (3.16)$$

where $\Delta Y_t^e = Y_t^e - Y^e_{t-1}$.

Two relationships were specified to describe new plantings and removals. New plantings were defined by an adjustment process,

$$N_t^* = A_{t+k}^* - A_{t-1} + R_{kt}^e - N_{Kt-1}, \qquad (3.17)$$

where N_t^* is desired new planted area, K is the time interval between initial planting and bearing, R_{Kt}^e is the acreage expected to be removed during the next k years, including year t, and N_{kt-1} ($\Sigma_{i=1}^{k} N_{t-i}$) is total acreage planted after year t-k-1.

Expected removals are represented as follows:

$$R_{kt}^e = b_1 A_{t-1}^0 + b_2(N_{kt-1} + A_{t-1} - A_{t-1}^0) + u_{5t} \quad (3.18)$$

where A_{t-1}^0 represents the old plants removed because of declining productivity and $(N_{kt-1} + A_{t-1} - A_{t-1}^0)$ represents the removals due to disease or insect damage.

The final expression for desired new plantings may be obtained by substituting (3.16) and (3.18) into (3.17), and consolidating terms. These manipulations yield the following equation:

$$N_t^* = d_1(\pi_t^e - \pi_t^*) + d_2(\pi_{At}^e - \pi_{At}^*)$$
$$+ d_3 \Delta Y_t^e + d_4 A_{t-1}^0 + d_5 N_{kt-1} + d_6 A_{t-1} + v_t \qquad (3.19)$$

The plant removal equation was specified as follows:

$$R_t^* = e_1 + e_2 A_t^0 + e_3 A_t^0(\pi_t^s - \pi_t^*)$$
$$+ e_4 A_t^0(\pi_{At}^s - \pi_{At}^*) + e_5 Z_t + e_6 N_{kt} + u_t \qquad (3.20)$$

where π_t^s and π_{At}^s are short-run expected profits for the crop and its substitute, respectively. The term, A_t^0 (removals due to the declining productivity), is entered as a multiplicative factor with the expected profit terms because removals are expected to be highly proportional to A_t^0. The variable, $Z_{t,}$ accounts for physical or institutional factors.

The total change in bearing acreage from one year to the next may be defined as

$$A_t - A_{t-1} = (1 - b_2)N_{t-k} - R_{t-1} + v_t \qquad (3.21)$$

Substituting equations (3.19) and (3.20) into (3.21) yields a reduced form equation for the net change in bearing acreage of a perennial crop from year t-1 to year t.

$$A_t - A_{t-1} = f_0 + f_1(\pi_{t-k}^{e} - \pi_{t-k}^{*}) + f_2(\pi_{At-k}^{e} - \pi_{At-k}^{*})$$
$$+ f_3 \Delta Y_{t-k}^{e} + f_4 A_{t-k-1}^{0} + f_5 A_{t-1}^{0}$$
$$+ f_6 A_{t-1}^{0}(\pi_{t-1}^{s} - \pi_{t-1}^{*}) + f_7 Z_{t-1}$$
$$+ f_8 N_{kt-k-1} + f_9 A_{t-k-1} + f_{10} A_{t-1} + v_t \qquad (3.22)$$

Explanatory variables in equation (3.22) are expected profit and yield expectations held in year t-k (k = years to reaching bearing age), the acreage of old plants in years t-k-1 and t-1, short-run profit expectations held in year t-1 (multiplied by old acreage in t-1), institutional or physical factors (represented by Z), the amount of non-bearing acreage as of t-k-1, and the total bearing acreage in t-1 and t-k-1.

The model is illustrated with an application to asparagus, a perennial vegetable crop. A major problem for estimating supply response was the lack of data for new plantings, acreage removed, and the age distribution of standing plants. Modifications of the basic model were necessary to allow estimation: expected profitability was approximated by output prices, deflated by an index of agricultural wages. Assuming normal long run profit is constant, only the expected price is left as an explanatory variable. Future expected profitability is estimated by a two year moving average of deflated prices. Alternative specifications, which expressed expected price as a geometrically weighted average of past prices, were tested with several values of the adjustment coefficient. The simple two-year average proved statistically superior.

Omitting variables for which data was unavailable, and assuming that old acreage is proportional to average total acreage ($\overline{A}_t$), the supply equation takes the form

$$A_t - A_{t-1} = B_0 + B_1 P_{1t-1}\overline{A}_{t-1} + B_2 P_{2t-k-1} + B_3 \overline{A}_{t-1} + B_4 \overline{A}_{t-k-1} + B_5 L_t + s_t \qquad (3.23)$$

where P_{1t-1} is price lagged one period deflated by wage rate index, P_{2t-k-1} is a two year average deflated price, s_t is a disturbance term, and L_t is a dummy variable to allow for unusual events.

Ordinary least squares is used to estimate equation (3.23) for asparagus production in California, the Midwest-East and the Northwest. The results for California and the Midwest-East were consistent with theoretical expectations. Results were less satisfactory for the Northwest, where acreage was relatively small and increasing through much of the period.

In the FM model, lack of data prevented estimation of the structural system. Only the reduced form of the model could be estimated. Structural parameters could not be recovered from the estimated coefficients. However, in the most recent work (French, King and Minami) separate replanting and removal functions have been estimated for cling peaches.

Baritelle and Price's (BP) Model

Baritelle and Price estimated a supply function for the Washington apple industry. In their model, production equals the number of trees multiplied by yield,

$$Q_t = \Sigma_i y_{i,t} A_{i,t} \quad (3.24)$$

where Q_t is total production in year t, $y_{i,t}$ is yield per tree for trees of age i in year t, and $A_{i,t}$ is the number of trees of age i in year t.

The number of trees equals the previous year's stock, adjusted for removals:

$$\Sigma_i A_{i,t} = \Sigma_i A_{i,t-1} + N_t - \Sigma_i L_{i,t-1} \qquad (3.25)$$

where N_t is the net change in trees due to economic reasons and $L_{i,t-1}$ is the numbers of trees of age i killed by frost.

The net change in the number of trees is related to new plantings less removals:

$$N_t = PL_t - R_t \qquad (3.26)$$

where, PL_t is new plantings in year t and R_t represents removals in year t.

New plantings and removals are functions of expected profitability:

$$PL_t = k\,[E(P)] \qquad (3.27)$$

$$R_t = h\,[E(P)] \qquad (3.28)$$

where E(P) is expected future profitability.

Because of data limitations, only the net changes in trees could be estimated. Thus,

$$N_t = g[E(P)] \qquad (3.29)$$

Losses due to natural attrition were specified a priori as fixed percentages of the population.

Expected future profitability was portrayed as a function of recent past prices. Because of the longevity of the investment and the associated uncertainties, grower behavior was assumed to depend on an average of prices for several past years. Cost effects were incorporated by deflating output prices by the index of prices paid:

$$g[E(P)] = k + \sum_{j=0}^{T} \beta_j P_{t-j} \qquad (3.30)$$

The net change in the number of trees planted is estimated as follows:

$$N_t = k + \sum_{j=0}^{T} \beta_j P_{t-j} + u_t \qquad (3.31)$$

where P_{t-j} is the average price received by Washington apple growers j years in the past. The equilibrium price is obtained by setting N_t equal to zero (plantings equal replacements) and solving for P_{t-i} assuming all lagged prices are equal. The Almon polynomial lag technique was used, so as to increase the degrees of freedom. The estimation results showed that response to price was increasing and then declining over time. The increasing supply response to the recent prices may be the result of two factors. First, growers may be hesitant to respond to current price. Second, the availability of some inputs tempers planting decisions; for example, nursery stock must be planted one to two years prior to its sale.

Conclusion

The models based on the adaptive expectations hypothesis are the Bateman model, the WG model and the HNP model. The empirical results in the Bateman model suggested that expected prices depended only on the most recent prices; the coefficient of adaptation was approximately1. Data limitations in the WG model forced reliance on a reduced form estimation, and the coefficients of price response could not be identified. The HNP model showed that expected price has a significant influence on replantings rather than new plantings, with an adjustment coefficient of 0.15.

In the French models, expected prices are based on the average profits of recent years. A simple average of recent prices was used to approximate the future expected price. In the BP model, expected price was assumed to be a function of recent past prices. This function was estimated with a polynomial approximation.

Several of the above models developed complicated structural equations to incorporate the unique characteristics of perennial production. However, estimation of those structural systems was not possible due to data limitations. Only reduced forms could be estimated and the structural parameters could not be recovered. Even if data were available, complete structural models with many variables could encounter estimation problems such as multicollinearity. Without sufficient data, a simple investment model thus may be a preferred source of equations for estimation.

CHAPTER 4

EMPIRICAL ANALYSIS OF THE APPLE INDUSTRY

The models described in the previous chapter are used to develop and specify a simple supply model. An empirical test of the model uses data for the national and Washington apple industries. The model explains new plantings in terms of expected price, fixed costs and previous capital stock. Alternative price expectations hypotheses were evaluated by fitting the models with different price expectation formulations.

Modeling Considerations

The endogenous variables in the previous models are net change in output, total output, new plantings and replantings, net change in bearing acreage, and net change in the number of trees planted. The selection of endogenous variables was determined by data availability. None of the above models include fixed capital costs as an explanatory variable. However, establishing an orchard means that a substantial irreversible fixed investment occurs at the beginning of the period with zero salvage value at the end. Thus, capital costs should be an important consideration for the long term investment.

Endogenous variable

Output decisions primarily involve plantings and removals. Current production respects an accumulation of past costs and efforts. Total bearing acreage does not vary much with price; instead, price influences the planting of new trees.

New plantings represent a long term investment decision based on expected profits during the life of the tree. Replantings are adjustments to replace unproductive or less productive trees. Replantings are influenced by new technology, natural or physiological factors, remaining expected profits from the trees, and the opportunity cost of land. To compare the explanatory power of different hypotheses about price expectations, new plantings is selected as the endogenous variable.

Explanatory Variables

An orchard requires a substantial irreversible fixed investment at the beginning of the production period. About 60 % of apple production costs are fixed cost. (Wade, James C., Gene N. Wright, and Michael W. Kilby, 1986, 6 pp). Expected revenues are based on the expected income streams during the life of the tree. Uncertainty about prices and outputs during this long planning horizon may cause growers to consider historical experience as a good indicator of future profits. Thus, price expectations based on past prices is likely to be important for new planting decisions. A perennial model should account not only for the expected prices of output but also the expected prices of inputs.

Each planting decision is a state variable (or potential constraint) for plantings in subsequent periods. To represent these interdependencies, the tree stock of previous year should also be included as one of the exogenous variables.

Consequently, explanatory variables for a new planting decision are expected prices during the bearing life, expected input costs, fixed costs of investment, and the previous capital stock:

$$NP = f(P, C , FC , A)$$

where NP is newly planted acreage, P is expected price, C is expected variable input costs, FC is fixed cost, and A is the previous capital stock.

Data Sources

National data for fresh apple prices from 1934 to 1988 are available in Agricultural Statistics (United States Department of Agriculture, 1935-1989). Average interest rates on new loans of the Federal Land Banks, also available in Agricultural Statistics, is used as a proxy for capital cost. Time series data on apple production costs are not available, so the indices of prices paid by farmers were used. GNP deflators (to convert nominal values to real values) and indices of prices paid by farmers are reported in Economic Report of the President (1988).

A comprehensive model can not be estimated with available data. Net change in bearing acreage is the only information available about planting behavior. Bearing acreage for the 1947-83 period is obtained from Fruits and Nuts Bearing Acreage. National acreage data from 1984 to 1988 and state acreage data from 1984 to 1987 are reported in Fruit and Tree Nuts, and Noncirtrus Fruit and Nuts Annual Summary, respectively. Data on new plantings and removals are not available. In the absence of data on new plantings, the net change in bearing acreage is used as a proxy for newly planted acreage.

Econometric Specifications

Net change in bearing acreage results from new plantings plus replantings minus removals.

Net change in bearing acres =	New Planting	+ Repalntings	- Removals

When removals are caused by natural and physiological factors, replantings equal removals and net change in bearing acreage will equal newly planted acreage. The estimation will be unbiased. When new technologies, improved varieties, and higher plant densities are introduced, less replanting is required to maintain the same level of production. The use of net change in acreage will underestimate new plantings because replanted area is less than removals. Finally, bearing acreage can be removed without replanting because of unprofitable production or higher opportunity costs of land. New plantings will again be underestimated by the net change in bearing acreage.

Time lags are important in estimating supply response. To capture the appropriate lag response, various hypothetical lags were estimated. The best statistical results were obtained when the variables explaining the net change in acreage were lagged eight years, implying a seven year lag between initial planting and realization of full production. This lag is consistent with the biological characteristics of apple trees. The normal gestation period for apple trees is five years, but trees are classified as "bearing" only when they begin to produce commercially significant quantities. Normal yield for apple trees is usually achieved in the sixth to eighth year after planting.

The relation between bearing acreage and new plantings is revealed in the following relationships:

$$BA_t = NP_{t-7} + (NP_{t-8} + \ldots + NP_{t-30}) - R_t - R_{t-1} - \ldots - R_{t-23} \quad (4.1)$$

$$BA_{t-1} = (NP_{t-8} + NP_{t-9} + \ldots + NP_{t-31}) - R_{t-1} - R_{t-2} \ldots - R_{t-24} \quad (4.2)$$

where BA is bearing acreage, NP is newly planted acreage, and R is removals minus replantings. Subtracting (4.2) from (4.1) gives,

$$BA_t - BA_{t-1} = NP_{t-7} - R_t - (NP_{t-31} - R_{t-24})$$

$(NP_{t-31} - R_{t-24})$ can be ignored because trees this old produce so little. Thus, net change in bearing acreage is the result of lagged new plantings and current net removals (removals minus replantings).

Efforts to estimate removals were made in this study. Removals were assumed to be a function of changes in planting density and short run expected profit, represented by the net change in yield and recent prices. However, neither of these variables was found to have a significant influence on the net change in bearing acreage. Hence, removals were assumed to be zero or small in magnitude. Net change in bearing acreage, $BA_t - BA_{t-1}$, is used as an approximation for newly planted acreage, NP_{t-7}.

The model to be estimated is specified as follows,

$$NP_t = f(P_t^e , A_{t-1}, I_t) \qquad (4.3)$$

where NP_t is newly planted acreage, P_t^e is the expected price deflated by the index of producer prices, A_{t-1} is the total bearing acreage in the previous period (representing the capital stock), and I_t is the costs of fixed investments, deflated by the GNP deflator. The coefficient on prices is expected to be positive because new plantings increase with increases in expected price. The coefficients on capital stock and fixed cost should be negative. Plantings should decrease with an increase in fixed cost, and a larger capital stock is expected to moderate the desire to expand production.

Naive, simple moving average, and Nerlovian adaptive expectations were used as alternative formulations of price expectations. Naive price expectations is represented by prices lagged one year. The moving average price is represented by averages between two and five years of past prices. Adaptive expectations are represented by a Koyck formulation. This expression is derived from equations for expected price and new plantings:

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

$$NP_t = a_0 + a_1 P_t^e + u_t$$

Current production can then be expressed as an adjustment of past production,

$$NP_t = \pi_0 + \pi_1 P_{t-1} + \pi_2 NP_{t-1} + v_t \qquad (4.4)$$

where $\pi_0 = a_0 \beta$

$\pi_1 = a_1 \beta$

$\pi_2 = (1-\beta).$

The relationship between expected price and new plantings (a_1) and partial adjustment ccoefficient (β) can be recovered from π_1 and

π_2. Adding the consideration of fixed costs and previous capital stocks to equation(4.4) gives the following equation:

$$NP_t = \pi_0 + \pi_1 P_{t-1} + \pi_2 NP_{t-1} + \pi_3 I_t + \pi_4 A_{t-1} \quad (4.5)$$

Equation (4.5) is used to examine the adaptive expectation hypothesis. This equation also can be used to test naive expectations
(π_2 not significantly different from zero). The estimates are based on annual data from 1959 to 1987 for the national models and annual data from 1961 to 1986 for the Washington models.

Results

The model is tested with data for national and Washington production. National data might contain offsetting trends among the various regions, so further tests with regional data were desired.

Washington is a leading apple growing region, producing between one-third and one-half of national output.

Three different price expectation hypotheses (naive, simple average and adaptive price expectations) are examined by comparing the results of alternative formulations of expected price. Equation (4.3) is applied to national and Washington state data to test naive and simple average formulations of price expectations. Equation (4.5) is used to test the naive and adaptive expectations hypotheses.

The National Models

The results for the national model (Table 1) give the best result (highest significant level) with the naive formulation of expected price. The use of simple averages of past prices gave poorer results as the length of the price series was increased. The statistical significance of the coefficient for price lagged one year and the insignificance of coefficients for the lagged dependent variable suggest that the adaptive expectations coefficient in the Nerlove model is approximately one. Future price expectations appear to be shaped by the price lagged one period. The adjustment coefficient of price expectation (Beta) is 0.78. Further, the Beta coefficient could be underestimated because uncontrollable random factors can cause observed plantings to be less than desired.

Both the naive and adaptive representations of expected price are significant, and it is hard to tell which approach is best represents farmers' actual behavior. The adaptive expectation form gives price the largest influence on new plantings. The coefficient on expected price is 1.7, implying a price elasticity of 0.04.

The overall performance of the models are good. The model using the naive representation of expected prices has the highest R-square and F-statistics. The previous capital stock and interest rate both have expected signs and highly significant t-statistics, confirming that capital costs and capital stock have a negative influence on new planting decisions.

Table 1. ESTIMATES OF NATIONAL SUPPLY MODEL WITH ALTERNATIVE PRICE EXPECTATIONS

(DEPENDENT VARIABLE IS NEWLY PLANTED ACREAGE)

	Independent Variables (a)					
Hypothesis	Constant	Expected Price	Lagged Bearing Acreage	Interest Rate	R2	F
Naive Expectations						
P(-1)	38.623	1.408	-0.072	-1.251	0.638	17.44
	(4.478)	(2.838)	(-5.235)	(-3.419)		
Moving Average Prices						
[P(-1) +P(-2)]/2	36.893	1.58	-0.071	-0.514	0.621	16.27
	(3.950)	(2.562)	(-5.042)	(-3.428)		
[P(-1)+P(-2)+P(-3)]/3	35.767	1.638	-0.068	-1.312	0.596	14.78
	(3.433)	(2.156)	(-4.762)	(-3.413)		
[P(-1)+....+P(-4)]/4	37.8	1.467	-0.067	-1.356	0.561	12.91
	(3.232)	(1.500)	(-4.417)	(-3.387)		
[P(-1)+...+P(-5)]/5	43.37	0.819	-0.064	-1.404	0.53	11.51
	(3.309)	(0.675)	(-3.934)	(-3.384)		
Adaptive Expectations						
	28.49	1.70 (b)	-0.057	-0.981	0.648	13.87
	(2.47)		(-3.16)	(-2.36)		

a. T-statistics are in parentheses.

b. Coefficient is derived from coefficients on lagged price (1.32; t-statistics is 2.66), and lagged new plantings (0.22; t-statistics is 1.30).

The Washington Models

Assuming the Washington state capital market is similar to the national one, the national interest rate can be used to represent fixed costs in the Washington model. The Cochrane-Orcutt estimate procedure is employed to eliminate serial correlation problems in the estimation of equation 4.3. Ordinary least-square is used to estimate equation 4.5.

The results (Table 2) are best for the naive and simple two-year average formulations of expected price. A three year moving average of prices gives the largest supply elasticity (0.18). The model with naive price expectations has the lowest elasticity (0.044). The adjustment coefficient from the adaptive expectations from the adaptive expectation model is 0.45, which is smaller than the national coefficient. This result suggests that Washiington farmers adjust their expectations more slowly than the rest of the nation toward the normal price level.

Interest rates have negative but insignificant impacts on new plantings; newly planted acreage will decrease with increased fixed costs. The insignificance of the estimate may reflect the inappropriateness of the assumption that the Washington and national capital markets are identical. The elasticity of new planting with respect to the interest rate is higher in Washington (elasticity = -0.07) than in the national model (elasticity = -0.035).

The coefficient on previous capital stock is significant and positive; the values range from 0.16 to 0.49. Previous capital stock has a larger influence on new plantings in the Washington model than in the national model. The positive signs of the coefficients conflict with theoretical expectations. One possible explanation for this result is that planted area has been expanding on a trend in recent years; because Washington is a part of the national market, regional capital stock is probably not a constraint on expansion. A further problem arises because removals of old varieties probably

Table 2. ESTIMATES OF WASHINGTON SUPPLY MODEL WITH ALTERNATIVE PRICE EXPECTATIONS

(DEPENDENT VARIABLE IS NEWLY PLANTED ACREAGE)

Hypothesis	Independent Variables (a)						
	Constant	Expected Price	Lagged Bearing Acreage	Interest Rate	Rho	R2	F
Naive Expectations							
P(-1)	-27.446	0.265	0.378	-0.111	0.648	0.608	13.42
	(-1.444)	(1.817)	(2.239)	(-0.195)	(4.254)		
Moving Average Prices							
[P(-1) +P(-2)}/2	-10.586	0.457	0.246	-0.514	0.343	0.597	12.87
	(-0.738)	(1.952)	(2.10)	(-1.18)	(1.825)		
[P(-1)+P(-2)+P(-3)]/3	-20.763	0.804	0.314	-0.414	0.304	0.662	16.65
	(-1.500)	(2.995)	(2.890)	(-1.056)	(1.593)		
[P(-1)+....+P(-4)]/4	-31.359	1.049	0.398	-0.29	0.297	0.676	17.66
	(-2.049)	(3.217)	(3.395)	(-0.741)	(1.554)		
[P(-1)+...+P(-5)]/5	-43.87	1.25	0.489	-0.043	0.428	0.661	16.58
	(-0.126)	(2.78)	(3.303)	(-0.093)	(2.369)		
Adaptive Expectations							
	-8.63	0.71 (b)	0.163	0.28	N/A	0.664	13.32
	(-0.89)		(2.30)	(-0.85)			

a. T-statistics are in parentheses.

b. Coefficient is derived from coefficients on lagged price (0.33; t-statistics is 2.32), and lagged new plantings(0.55; t-statistics is 3.34).

caused net change in bearing acreage to greatly underestimate new plantings.

Comparisons of the Results

The naive and adaptive expected price performed well with national data, whereas the three year moving average and adaptive expectation models performed better with the Washington data.

Comparing our results with some of the empirical results of Marc Nerlove (1956) (Table 3), a negative correlation between the price elasticities and expectation coefficients is apparent. The lower the price elasticity, the higher the coefficients. When supply is more price-elastic, expectations are formed more cautiously and depend more on past prices. Farmers adjust their expectations slowly towards the normal equilibrium level and the adjustment coefficient is small.

Table 3. Comparison of Price Elasticities and Expectation Coefficient

region	Price Elasticity	Coefficient of expectations
Apples		
National Model	0.04	0.78
Washington Model	0.12	0.45
Cotton*	4.53	0.04
Wheat*	1.18	0.37
Corn*	0.35	0.25

* Source: Nerlove, Marc, "Estimates of the Elasticities of Selected Agricultural Commodities." Journal of Farm Management, Vol. 38,1956.

Planting an orchard is more complicated than annual production. Price expectations hypotheses which have proved so successful for field crops may not be appropriate for tree crops. Although future expectations are thought to be shaped by several past prices, due to the longevity of the investment and associated uncertainties, the empirical results showed that naive, simple average, and adaptive expectations all yielded satisfactory results. Thus, each formulation has something to offer to empirical models.

Simple moving averages may be the most useful representations of expected prices when production and prices fluctuate substantially over time. Producers are likely to form expectations on the basis of average profits during several recent years. In perennial production, the biennial cycle may prevent growers from adjusting on an annual basis, and a simple moving average serves to combine off years and the peak years.

The difference between the naive and adaptive expectations are not great for the apple market model. Nerlove's non-iterative formulation implies that producers adjust current production on the basis of the previous production level. That is,

$$Q_t = \pi_0 + \pi_1 P_{t-1} + \pi_2 Q_{t-1}$$

where Q is total supply and P is price. Applying this concept to perennial production, producers will adjust current production on the basis of total bearing acreage instead of just new plantings.

Modifying the Nerlovian partial adjustment model from equation (4.5) yield

$$NP_t = \pi_0 + \pi_1 P_{t-1} + \pi_2 A_{t-1} + \pi_3 I_t \qquad (4.12)$$

This equation is the same as the above naive expected price model. Therefore, equation (4.3) can also be represented as a modified adaptive expectations model for perennial crops.

Conclusion

Based on the empirical results, it is difficult to tell which hypothesis best represents grower behavior. The estimated supply elasticities are very low. It may be necessary to develop and test several alternative expectation hypotheses. One of these would be rational expectations. When production experiences a sudden discontinuous shift, past prices can not be expected to prevail in the future. Technical changes, such as improved varieties, cause growers to change the way expectations are formed. Future expectations must be shaped on the basis of the changed economic structure. The rational expectations hypothesis could be a more attractive representation of expectations in this transitional period. However, limits to available data represent important constraints to testing this hypothesis.

CHAPTER 5

CONCLUSIONS

This thesis studied three hypotheses about price expectations and reviewed five supply response models for perennial crops. An empirical model for the apple industry was developed to test alternative representations of expected prices. The naive and adaptive expectation model performed well with national data, whereas moving averages of price and the adaptive expectations model performed better with Washington data.

The research project encountered several difficulties. First, the explanatory variables changed over a limited range. Estimation of supply response was based on a range of prices between 6.9 to 13.4 cents per pound for national data and 4.5 to 19.4 cents per pound for the Washington model. The real interest rate ranged from 11.6 percent to 20.7 percent. Supply response to changes outside the above intervals are unknown. Second, the estimates are biased by using the net change in acreage as a proxy for new plantings: new plantings are underestimated when removals are not equal to zero; expected planted acreages may diverge from the desired planted acreage because of unforeseen complications; and bearing acreage could differ from planted acreage because of losses during the gestation period. Finally, the proxy for production costs can be biased. To improve estimates of supply response for perennial crops, better data are needed to describe new plantings, removals, the age distribution of trees, production costs, and climatic conditions.

Rapid technological change in the U.S. apple industry leads to further implications for research. High density plantings, new varieties, and grafting with higher yielding clonal varieties will increase yields markedly in the future. Increased acreage will become less important to growth in total production. Acreage response will be only a minor part of total supply response.

Technological change also will affect the lag between price changes and output response. Substantial yields will be obtained in the third or fourth year after planting. Costs of orchard establishment will also be increased because of higher plant densities. These higher costs may cause producers to revise the way they form expected prices, encouraging them to use more historical information and paying more attention to projections of future demand. Rational expectations perspectives may become increasingly relevant.

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