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Agricultural Price Expectations: An Erroneous, but Better Approach to Measurement

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Abstract

The subjective, market level expectation of price is an unobservable which at best can be measured with error. The usefulness of the past and current cash prices and futures prices are considered. An errors-in-variables model of price expectations is introduced and applied in a model of U. S. aggregate soybean supply.

Introduction

The problem to be addressed in this paper will be the measurement of the market level expectation of a commodity price. The importance of such a measure arises in econometric market models for agricultural commodities. As has long been recognized the supply of such commodities is dependent upon the expectation of uncertain future prices. An expanded version of this present paper presents a detailed review of alternative measures and their usefulness. The objectives of this paper will be to briefly review the alternatives, consider their relative usefulness and finally present a framework which allows their introduction to linear econometric models. An application to U. S. aggregate soybean supply is presented.

Alternative Sources of Information Concerning Price Expectations

Arbitrage in and between cash and futures markets link the unobservable subjective price expectations E_t to 1) the series of past cash prices $\{P_{t+1-i}\}$, 2) the final cash price at harvest P_{t+1}, and 3) the futures price of the harvest contract observed at t, $F_{t+1,t}$. In addition, the subjective price expectation is linked through producers' efforts to maximize expected profits to their production choices: X_t. Thus there exist several observables linked to the unobservable E_t. The problem of measurement of higher moments of subjective distributions for risk averse decision makers will be addressed in a future paper.

Alternative Measures of Expectations

First, suppose that the only information available upon which expectations can be based is the time series of past cash prices: $\{P_{t+1-i}\}$. It is consistent with the hypothesis of expected profit maximization that the decision maker will attempt to use these prices to formulate a forecast that minimizes the forecast error. In time series terminology an optimal extrapolation would be formed as a weighted average of the past prices. That is, following Wold [1954] any strictly indeterministic time series can be regarded as generated by a linear combination of the past history of a white noise process $\{U_t\}$; that is,

$$1)\qquad P_t = \mu + \sum_{i=0}^{\infty} \Psi_i U_{t-i}$$

$$= \mu + \sum_{i=0}^{\infty} \Psi_i B^i U_t$$

$$2)\qquad = \mu + \Psi(B)U_t$$

where $U_t \sim N(0,\sigma^2)$ and B represents a backward shift operator.

A convenient means of representing the process using a finite number of parameters is with an ARIMA model:

$$3)\qquad \phi_p(B)(1-B)^d P_t = \theta_q(B)\ U_t$$

where $\phi_p(B) = \sum_{i=0}^{p} \phi_i B^i$ and

$$\theta_q(B) = \sum_{i=0}^{q} \theta_i B^i$$

which can be rewritten (by appropriate definition of filters) in a purely autoregressive form as:

$$4)\qquad \phi_p(B)(1-B)^d \theta_q(B)^{-1} P_t = U_t$$

$$\pi(B)P_t = U_t$$

$$P_t = \tilde{\pi}(B)P_t + U_t$$

Within this framework the adaptive expectations hypothesis of Nerlove can be seen as imposing restrictions on 4) prior to estimation.

Specifically, by the adaptive expectation hypothesis

5) $$E_t = E_{t-1} + \lambda(P_{t-1} - E_{t-1})$$

This would be an acceptable rule which would minimize the sum of squared forecast errors only if it were derivable from the process which cash prices were assumed to follow. This process can be determined by elimination of all E_{t-1} from 5) by substitution:

6) $$E_t = \lambda \sum_{i=1}^{\infty} (1-\lambda)^{i-1} P_{t-i}.$$

A price process which has a conditional mean in the form of 6) is:

7) $$P_t = \lambda \sum_{i=1}^{\infty} (1-\lambda)^{i-1} B^i P_t + V_t \qquad V_t \sim N(0,\sigma_V^2)$$

After simplification, 7) can be represented by

8) $$(1-B)P_t = (1-\theta B)V_t$$

where $\theta = 1 - \lambda$.

Continuing this simplification, we have by appropriate definition of filters

9) $$(1-B)(1-\theta B)^{-1} P_t = V_t,$$

$$A(B)P_t = V_t,$$

$$P_t = \tilde{A}(B)P_t + V_t.$$

The conclusion can be drawn that the adaptative expectations hypothesis minimizes the sum of squared forecast errors possible with a linear combination of past prices only if the actual price process follows a process which can be characterized as ARIMA (0,1,1).

An important aspect of the above extrapolative measures is that exact measures of the expectation are postulated; i.e., from 4) and 9) we have:

10) $$E_t = E(P_{t+1})_t = \tilde{\pi}(B)P_t$$

or

$$E_t = E(P_{t+1})_t = \tilde{A}(B)P_t$$

As Muth [1961] and Nelson [1976] have pointed out, it is not difficult to find a market structure which would render this simple stochastic process of price evolution inappropriate. Even without stepping into the theory of rational expectations, it appears reasonable to postulate that in the presence of information other than past prices the extrapolative measures would at best provide erroneous measures of the unobservable; e.g., a more reasonable specification might be:

11) $$E_t = \tilde{\pi}(B)P_t + U_t$$

$$U_t \sim N(0,\sigma^2)$$

At an intuitive level, the past price series ignores new information available after the last cash price was determined. If there existed a means of capturing that information it can be assumed that expected profit maximizers would do so and incorporate that information into the forecast. Although futures markets provide valuable sources of information in addition to the actual closing price, the focus here is on the closing futures price for the harvest contract observed at planting time. The idea that futures could be useful is not new, see Working [1942], Brennan [1958], Peck [1976], Gardner [1976], Weaver et al. [1976]. In each of these cases, the hypothesis was maintained that the futures price provides an exact measure of the price expectation, i.e., $E_t = F_{t+1,t}$.

Intuitively, this is a strong assumption which ignores any bias which may exist in futures markets as a result of: i) risk aversion, ii) transactions costs, iii) imperfect information, or iv) transportation costs. Despite extensive empirical study of the existence of bias, the evidence remains weak due to its dependence on accurate measurement of unobservable price expectations. Without belaboring this issue, it appears there exists an adequate basis to conclude a more general model of the relation between E_t and $F_{t+1,t}$ may be in order. Specifically, a relation is needed which allows 1) bias to exist, 2) bias to vary over time, and 3) recognizes the fact that $F_{t+1,t}$ may be at best an erroneous measure of E_t, e.g.,

12) $$E_t = \alpha_o + \alpha_1 F_{t+1,t} + U_t.$$

Equations 11) and 12) present two alternative specifications of erroneous measures of expectation. However, a model incorporating both the optimal extrapolation and the futures price may provide a more accurate measure of E_t. This possibility is refuted by the following argument. To the extent that past prices are valuable for forecasting future cash price, the futures price will incorporate that information even in the absence of efficiency of futures trading. That is, suppose

13) $$F_{t+1,t} = F(I_t)$$

where I_t is the set of all available relevant information at t.

If $\{P_{t+1-i}\} \varepsilon I_t$, then $F_{t+1,t}$ and $\tilde{\pi}(B)P_t$ would provide redundant measures of the information contained in the past price series. This proposition can be tested empirically by investigating the independence of the differential between $F_{t+1,t}$ and P_{t+1} and the past price series. That is, in the context of the regression

14) $$P_{t+1} - F_{t+1,t} = \lambda_o + \sum_{j=1}^{\infty} \lambda_j P_{t+1-j} + E_j$$

the proposition can be posed as the following hypothesis

15) $$H_o: \lambda_j = 0 \quad \forall \quad j = 1, \ldots \infty$$

Results of tests of this joint hypothesis for a number of combinations of cash and futures wheat prices are reported in the expanded version of this paper. In sum, results supported the intuition that futures prices indeed incorporate all useful information contained in the past cash price series even when markets were spatially separated. By implication the use of both past and futures price would be redundant. Proceeding with the futures price, the remaining problem is to specify the relation between actual and expected cash prices, futures prices and choices in a model that incorporates all available information.

An Errors in Variables Model of Price Expectations

Consider the following general model for the choice of the supply of Y_t:

16) $$E_t = \alpha_o + \alpha_1 F_{t+1,t} + U_t$$

17) $$P_{t+1} = \beta_o + \beta_1 E_t + V_t$$

18) $$Y_t = \gamma_o + \gamma_1 E_t + \gamma_2 Z_t + \varepsilon_t$$

Choice of Y_t is hypothesized to be determined by relative expected prices. Consistent with this, all prices will be interpreted as relative. For example, equation 16) states that the relative expected output prices are linearly related to relative futures prices. In this general form, the model can be thought of as a block recursive simultaneous equation model. In its present form the model is not identified; however, intuition suggests several prior restrictions which allow identification of the parameters of equations 16) - 18). Specifically, if $F_{t+1,t}$ incorporates all relevant information available at time t, then U_t and Z_t may be assumed independent. Secondly, it is intuitive that if information which occurs between planting (t) and harvest (t+1) is white noise, then it is reasonable to restrict 17) such that

19) $$E(P_{t+1}) = E_t$$

That is, the following prior restrictions appear reasonable:

$$\beta_o = 0, \quad \beta_1 = 1.$$

Imposing these restrictions, we may write the reduced form of the structural system in one of the two following ways:

<u>Alternative 1</u>

20) $$P_{t+1} = \alpha_o + \alpha_1 F_{t+1,t} + U_t + V_t$$

21) $$Y_t = \gamma_o + \gamma_1\alpha_o + \gamma_1\alpha_1 F_{t+1,t} + \gamma_2 Z_t + \gamma_1 U_t + \varepsilon_t$$

<u>Alternative 2</u>

20') $$P_{t+1} = \alpha_o + \alpha_1 F_{t+1,t} + U_t + V_t$$

21') $$Y_t = \gamma_o + \gamma_1 P_{t+1} + \gamma_2 Z_t + \varepsilon_t - \gamma_1 V_t .$$

Comparing the appropriate estimation methods for the two alternatives, it is apparent that non-linear Zellner efficient estimators of 20) and 21) with cross-equation constraints would provide maximum likelihood estimates of reduced form parameters. However, our interest lies in the structural parameters and, more importantly, their statistical significance. Although these parameters can be identified their distributions would have to be calculated indirectly from the estimated reduced form error variance-covariance matrix $\hat{\Omega}$ under appropriate identification restrictions. As is well-known, derived structural equation error variance-covariances matrices Σ need not contain strictly positive variance estimates. To ensure this property, the reduced form estimation would have to be appropriately constrained. Alternative 2 provides a basis for a clearly less complex estimation method. Equations 20') and 21') can be thought of as partial reduced forms which represent a linear in parameters, recursive (in variables, not error structure) simultaneous equations system. Although P_t is by hypothesis correlated with V_t 20') suggests an obvious instrument which by hypothesis is independent of V_t. To accommodate a non-diagonal error structure a three stage least squares approach will provide consistent and asymptotically efficient estimates, which due to the form of 20') and 21'), will be estimates of the structural equation parameters. This result allows the use of the reduced form $\hat{\Omega}$ to investigate the significance of indirectly estimated structural parameters.

<u>An Application to U. S. Soybean Production Supply</u>

As an example application of such a model, Tables 1 and 2 report results for a model of U. S. annual soybean production. The empirical version of the model described by equations 16) - 18) and 20') -21') specified soybean supply as a function of expected relative prices (soybean/corn, wheat/corn, oats/corn); the fertilizer price index relative to expected corn price, and a trend variable. Each unobservable expected output price ratio was expressed as a linear function of the corresponding relative future prices following equation 17). Each cash closing price ratio was related to the unobservable relative expected price ratio following 17). The final structural system included one supply equation and six price relations. The reduced form of the system included three price relations similar to 20') and one supply equation similar to 21'). The impact of government policy on supply of soybeans and expectations is the subject of on-going research; however, for the current model the hypothesis is maintained that its expected effects are incorporated into the futures prices. The tables report three specifications: i) exact, which assumes $E_t = F_{t+1,t}$; ii) spot, where P_{t+1} in equation 20') is measured by the annual average cash market specific prices, e.g., # 2 Hard/Dark winter wheat marketed in Kansas City; and iii) average, where P_{t+1} in equation 20') is measured by U. S. annual and market average price received by farmers for all grades.

Data were collected from Agricultural Statistics and The Wall Street Journal. Results are based on a sample of annual average data (1948-1978). Estimated 't'-values, and a generalized measure of R^2 suggested by Aigner [1971] are also reported. Specifically,

$$\tilde{R}^2 = \{1 - \exp[2(L_o - L_{max})/T]\}$$

where L_o is value of likelihood when all slope coefficients are restricted to zero and L_{max} is the unrestricted maximum.

Table 1. Structural Co-efficient Estimates (1949-1977)

	Spot	U. S. Average	Exact
Soybean Supply			
Constant	-.676 (1.201)*	-1.213 (2.149)	-.017 (.090)
Expected Relative Prices:			
Soybean/Corn	.257 (2.403)	.615 (2.491)	.150 (2.720)
Wheat/Corn	-.338 (1.800)	-.302 (1.640)	-.156 (1.509)
Oats/Corn	1.773 (1.382)	1.509 (2.055)	.486 (1.246)
Fertilizer/Corn	-.273 (1.451)	-.393 (2.501)	-.230 (1.073)
Trend	.044 (18.113)	.043 (19.362)	.0418 (15.709)
Expected Price Equations			
Soybean/Corn:			
Constant	.627 (1.952)	.983 (2.909)	
Futures	.691 (4.630)	.522 (3,349)	
Wheat/Corn:			
Constant	.816 (3.828)	.800 (3.821)	
Futures	.469 (3.085)	.434 (2.902)	
Oats/Corn:			
Constant	.334 (3.154)	.275 (2.759)	
Futures	.403 (2.105)	.487 (2.690)	
Fertilizer/Corn:			
Constant	.175 (1.723)	.037 (.211)	
Futures	.738 (5.574)	.989 (4.280)	
$\tilde{R}^2$	.9252	.9289	.9752

*t-statistic

Table 2. Elasticities of Soybean Supply with Respect to Changes in Nominal Expected Prices

	Model		
Expected Price	Spot	U.S. Average	Exact
Soybeans	.667	1.594	.318
Wheat	-.615	-.525	-.215
Oats	1.223	1.017	.266
Corn	-.249	-.308	-.217
Fertizer	-1.026	-1.778	-.152

What conclusions can be drawn from these results? First, a test of the exactness of the measurement of expectations offered by futures prices can be obtained by simultaneously placing a restriction of zero on the intercept and unity on the slope coefficient of each of the price equations of the form of 20'). The results of an F-test based on such restrictions are dramatic ($F_{8,101}$ = 157.1105 for both the case where average and spot prices are employed) and firmly reject the hypothesis of exactness. Comparing the spot versus the U. S. average model it is apparent that the fit of these alternatives as indicated by the generalized R^2 is nearly identical. The pattern of signs of coefficients is generally robust across the models although minor variation is found in the degree of significance of the coefficients. This suggests that readily accessible cash and futures market spot prices may be of great use in forecasting supply due to their expectational content. Finally, Table 2 reports price elasticities of supply. These represent elasticities with respect to changes in nominal expected prices. As can be seen the estimates are not robust with respect to which cash price was used. Thus, although for forecasting purposes the choice of cash price appeared to be unimportant the reverse is true for specific price policy analysis. This suggests the need for more careful consideration of which cash price measure is appropriate. Perhaps the most dramatic general result is failure of elasticity measures to be robust between the exact and errors-in-variables models. This illustrates the importance of acknowledging the existence of error in measurement of expectations. Despite the absence of a substantial improvement in fit due to the errors-in-variables specification, its intuitive appeal over the exact model suggests that continued research may find it a fruitful means of incorporating indicators of price expectations.

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