

INFLATIONARY EXPECTATIONS AND THE
VALUE OF U.S. FARM REAL ESTATE:
SOME CONSISTENT ESTIMATES

by

W. J. Martin and E. O. Heady

CARD Working Paper

P82-1

February 1982

Paper presented to the Southern Agricultural Economics
Association Meetings, February 7-10, 1982, Orlando, Florida

ABSTRACT

In a number of recent papers, Martin Feldstein has hypothesized that expected inflation may increase the real value of assets such as farm real estate. In this paper, simple models of the value of U.S. farm real estate were developed to test this hypothesis. Both adaptive expectations and "rational" interest rate-based expectations of future inflation were considered. Adaptive expectations measures for expected inflation generally suggested a negative impact of inflation on real estate value. The interest rate-based expectation measures had a positive coefficient in all cases but only in one case out of six was this coefficient significant.

INFLATIONARY EXPECTATIONS AND THE
VALUE OF U.S. FARM REAL ESTATE:
SOME CONSISTENT ESTIMATES

The value of U.S. farm real estate is enormously important in U.S. agriculture. In 1979, U.S. farm real estate was valued at \$545.6 billion, or just under 80 percent of total farm assets (Hottel and Evans, p. 63). For comparison purposes, this was approximately a quarter of the value of U.S. Gross National Product in that year. Recently, it has been suggested that the real value of farm real estate may be affected by the rate of inflation (Feldstein, 1980b). This paper explores the role of this previously ignored factor in the determination of farm real estate value.

Under a general inflation, both the nominal return to farm real estate and its nominal value will increase. Conventionally, the real price of land would not be expected to change. In several recent articles, Martin Feldstein (1980a, 1980b) has developed theoretical models in which anticipated inflation increases real asset prices because of the characteristics of the U.S. income tax system (1980a, p. 915). If the hypothesis presented by Feldstein is applicable to the U.S. farm real estate market, it has potentially dramatic implications. If the inflation rate should fall, some of the real capital gains which economists have been attempting to measure (eg Plaxico and Kletke) could disappear.

In this paper, a number of models were used to test Feldstein's hypothesis. Initially, the ratio of real estate value to returns was

expressed as a function of anticipated inflation and other variables such as the rate of growth and variability of returns. In a second set of models, an explicit assumption was made about the formation of expectations of returns to real estate, and the value of real estate was treated as the dependent variable. In all of the models used, the null hypothesis was that inflation did not affect the value of farm real estate.

Prior to the presentation of the econometric results, the underlying theoretical determinants of real estate value need to be considered. The basic elements of Feldstein's theoretical argument are outlined in the next section of this paper. Following that discussion, some of the characteristics of suitable dynamic empirical models are reviewed. The details of the data used in this analysis are given in the following, third, section of the paper. The estimation results are presented in the fourth section while a summary and conclusions are given in the final section. Appendix 1 contains details on the sources and definitions of the input data set. Appendix 2 presents the mathematical derivation of estimable equations from the original models containing unobservable variables.

THEORETICAL DETERMINANTS OF LAND VALUES

Under the assumption of perfect knowledge, the value of a durable asset such as farm land is determined by the formula:

$$(1) \quad V(t) = \int_{\zeta=t}^{\infty} R(\zeta) \cdot e^{g(\zeta-t)} \cdot e^{-r(\zeta-t)} d\zeta \text{ or}$$

$$V(t) = \int_{\zeta=t}^{\infty} R(\zeta) \cdot e^{(g-r)(\zeta-t)} d\zeta$$

where $V(t)$ = the value of the asset at time t ;

$R(t)$ = net income derived from the asset in period t

g = the expected growth rate in nominal income from this asset,
and

r = the nominal rate of discount for future returns.

Clearly, this formulation implies that both the current level of net income and its expected growth rate influence the value of land. The importance of the expected growth rate, and not just the income level, has been emphasized by Melichar and others. For unchanging r and g , the function can be integrated to give the simpler form:

$$V(t) = R(t) \cdot [r-g]^{-1}$$

From this formula, it is clear that the growth rate of net income influences the ratio between asset value and net returns.

The real rate of growth in net returns is the relevant factor in the relationship between value and return. In general, inflation will raise interest rates (and the nominal discount rate) by approximately the expected rate of inflation (Feldstein, 1980a, p. 313). If both

the expected nominal discount rate and expected income growth are augmented by π because of a general inflation, equation (3) becomes:

$$V(t) = R(t) \cdot [(r_0 + \pi) - (g_0 + \pi)]^{-1} = R(t) \cdot [r_0 - g_0]^{-1}$$

Clearly, in this situation, expectations of future, general inflation do not affect the current value of the asset. A continuing inflation will increase $R(t)$ and $V(t)$ in the same proportion through time. Thus, an inflation is neutral in that it does not affect the real value of the land or the ratio $V(t)/R(t)$.

Feldstein (1980a, 1980b, 1980c) has argued on theoretical grounds that inflation will, in fact, not be neutral in its effects on asset prices. Because of the structure of the tax system, he argues that inflation should increase the real price of land and other physical assets such as gold.

The gist of his argument (1980a) is that, in a stationary economy with inflation at rate π :

- (a) Land and other physical assets L yield two returns
 - (1) Real net income per unit... R
 - (2) An inflationary increase in value at a rate... π .
- (b) Bonds and other money denominated deposits B have one return R , equal to the nominal rate of interest. This return includes an expectation of inflation, π , and a real interest rate component, i .
- (c) Corporate stocks, K , yield both a dividend, d , and capital appreciation at rate π .

In the absence of uncertainty and of taxation, competition between investors should cause the ratio of net marginal product to asset price (P) to be equated for each asset. Thus, with zero inflation:

$$(2) \quad \frac{R}{PL} = i = \frac{d}{PK}$$

and with a positive rate of inflation

$$\frac{R}{PL} + \pi = i + \pi = \frac{d}{PK} + \pi$$

Feldstein points out that, under inflation, the U.S. tax system gives relatively favorable treatment to the returns to land and other physical assets. The nominal return occurring as inflationary capital gains is subject to income tax, but this is levied at a reduced rate, c , and can also be deferred until the sale of the land. By contrast, the inflationary component of bond returns is taxed at the ordinary income tax rate θ . He also argues that the dividend return on corporate stocks is depressed by inflation because of inadequately adjusted depreciation allowances. Thus, under inflation, the effective tax rate on corporate returns can be written $(\theta + \lambda\pi)$ where λ represents the (assumed linear) effect of inflation on corporate income taxes.

Introducing a tax structure with the characteristics described by Feldstein, we obtain a nominal returns equality of:

$$\frac{(1-\theta)R}{PL} + (1-c)\pi = (1-\theta)i + (1-\theta)\pi = \frac{(1-\theta-\lambda\pi)d}{PK} + (1-c)\pi$$

Converting all of these rates of return into real terms by subtracting π , we obtain

$$(3) \frac{(1-\theta)R}{PL} - c\pi = (1-\theta)i - \theta\pi = \frac{(1-\theta - \lambda\pi)d}{PK} - c\pi$$

On the basis of previous empirical evidence, Feldstein incorporates a maintained hypothesis that the real interest rate, i , is a constant, While R and d are affected by inflation, they are known constants at any point in time. Given these assumptions, it is clear that the effect of an increase in inflation from zero to π is different for each term in the equality. Since θ is greater than c , the second term falls more than the first. Inadequate tax depreciation allowances, $\lambda\pi$, also cause the third term to be reduced by more than the first. To restore the equality, Feldstein argues that PL must rise and that PK will fall (1980a). Using plausible parameter values in a model slightly more general than the one presented here, Feldstein suggests that an increase in the rate of inflation from zero to 10 percent would double the price of land (1980a, p. 316).

The model presented above is grossly over-simplified in ignoring the effects of uncertainty. Its usefulness is to illustrate the nature of the effect hypothesized by Feldstein. In one paper, Feldstein (1980b) generalized the analysis to include uncertainty in an overall portfolio analysis. This generalization of the theory affected the likely size of the responses but did not alter the qualitative conclusions.

Before going further, it is worthwhile to illustrate the nature of the increase in land value hypothesized by Feldstein. For a given increase in the inflation rate, it is a one-off increase in value, not to be confused with the continuing rise in land prices under inflation. If the rate of inflation increased from π_0 to π_1 , at time t_0 , the time path of land prices would be as displayed in Figure 1. Prior to t_0 , real estate values would be increasing at the rate π_0 , after t_0 , values would rise continuously at the higher rate π_1 .

The relationship postulated by Feldstein is intuitively appealing, particularly given the dramatic increases in farm real estate prices experienced during the 1970s. The theoretical argument (Feldstein, 1980b) is also convincing under the highly simplified assumptions used. Feldstein's maintained hypothesis that the real rate of interest is unaffected by inflation has, however, been the subject of much controversy in the literature (e.g., Brown and Santoni, Kreicher). Even accepting Feldstein's theoretical models, their implications may not be relevant to the farm real estate market if:

- (a) the farm real estate and other asset markets are not sufficiently inter-linked to allow the hypothesized portfolio adjustment to occur, or
- (b) individual portfolio holders are not adequately informed about future inflation and tax rates.

Previous analyses of the farm real estate market (e.g., Pope et al) have not included the inflation rate in the determinants of land prices. Tweeten (1980, p. 860) included the effects of the income tax concession

for capital gains on land in his conceptual model but dismissed it as insignificant in practice. Since testing the maintained hypothesis of a constant real interest rate is outside the scope of this study we have chosen to directly test Feldstein's hypothesis that an increase in the expected rate of inflation will increase the value of farm real estate.

Empirical models to test the hypothesized relationship are formulated in the next section.

EMPIRICAL MODELS

The theoretical models discussed previously assume knowledge of future income levels, income growth rates, and levels of inflation. An empirical model must take into account the fact that the future values of these variables can only be estimated by participants in the farm real estate market. The method by which market participants form their expectations will have a major influence upon the dynamic responses observed.

Pope, et al. reviewed a number of econometric models of U.S. farmland prices. They concluded (p. 115) that the simultaneous models reviewed generated forecasts inferior to both Klinefelter's single equation econometric model and to 'naive' time series models. Taking this into account, a single equation econometric model approach was chosen for this study.

Feldstein's complete model (eg 1980b) can be viewed as a simultaneous system in which the price of each asset is endogenous. The exogenous variables are: (i) The expected rate of inflation, (ii) Net

returns from each asset, (iii) The variability in each category of net returns, (iv) The expected growth rates of net returns, (v) The structure of the tax system, and (vi) The real interest rate.

In this analysis, attention focussed on a single reduced-form equation from the system. Obviously, variable (i), expectations of the inflation rate, needs to be included in the equation. The levels of (ii), (iii) and (iv) were included for real estate only since changes in these parameters for other assets will primarily affect the value of the other asset. The structure of the tax system is assumed approximately constant throughout the study period and thus was not explicitly modelled. Following Feldstein, the real interest rate was assumed to be approximately constant and hence was not included in the model.

The models estimated can be thought of as reduced-form "demand"¹ functions for farm real estate where both current and potential land owners base their demands upon the same set of variables. This simple approach was chosen to provide a preliminary test of Feldstein's model. If the effect is as large as Feldstein's numerical example (1980a, p 316) would suggest, then it should be revealed even with a fairly simple testing methodology.

A number of variables used in other studies of the farm real estate market (Pope et al., p. 109) were deliberately excluded from this model. In particular, the general price level was excluded since its effect was postulated to operate only through the net returns variable. Government programs were also excluded because their primary effect should be

through the net returns variable.² Variables for farm area and crop yield were used in some other models to reflect technological economies, but their effect at the national level depends upon the demand for output. Any impact of these variables at the national level seems best measured directly through the net returns variable. Expected capital gains were viewed as following from income expectations, rather than as an exogenous factor.

In an empirical model of the real estate market, the treatment of expectations is particularly important. For the most part, it was assumed that individuals' expectations of net returns and the growth rate of net returns are formed by an adaptive process such as:

$$(4) \quad (R^*_t - R^*_{t-1}) = a(R_{t-1} - R^*_{t-1})$$

where R^*_t = the expectation of variable R at time t;

R_t = the actual value of R at time r; and

$$0 \leq a \leq 1.$$

Jacobs and Jones (p. 269) note that this process provides a minimum mean squared error forecast relative to the class of all linear constant coefficient functions of R, if R is generated by a process in which the mean does not have a trend. Nelson (p. 558) points out that this process will also generate weakly "rational" forecasts if the data series can be represented by a first order moving average in the first differences.

Where the mean of the process generating a particular variable does have a time trend, the simple adaptive expectations model will give

biased predictions. In this situation, a two-level adaptive rule is an unbiased, minimum mean-squared error predictor (Jacobs and Jones, p. 270). Such a process can be represented by:

$$(5) \quad (R_t^* - R_{t-1}^*) = a(R_{t-1} - R_{t-1}^*) + C_t^* \text{ and}$$

$$(6) \quad (C_t^* - C_{t-1}^*) = d(R_{t-1} - R_{t-1}^*)$$

where $C_t = R_t - R_{t-1}$ = the observed change in R_t ;

$C_t^* = R_t^* - R_{t-1}^*$ = the expected change in R_t (trend); and

$$0 \leq a, b \leq 1.$$

Jacobs and Jones (p. 276) concluded that such a rule accurately represented the formation of price level expectations reported in the Livingston Survey. It seems plausible that expectations of real estate returns might be represented by this type of process.

Adaptive learning rules were used to specify expectations regarding the level of net returns and the real growth of these returns. Because the real growth rate displayed no evident trend, a single stage adaptive process was postulated to be adequate for this variable. Since nominal returns displayed a marked trend, a two-level adaptive process was considered as well as the single adaptive process.

A three-year moving-variance term was used as an estimator of the riskiness of real net returns from farming. Under the hypothesis of utility maximization with risk aversion, it was expected that this term would have a negative effect on real estate values.

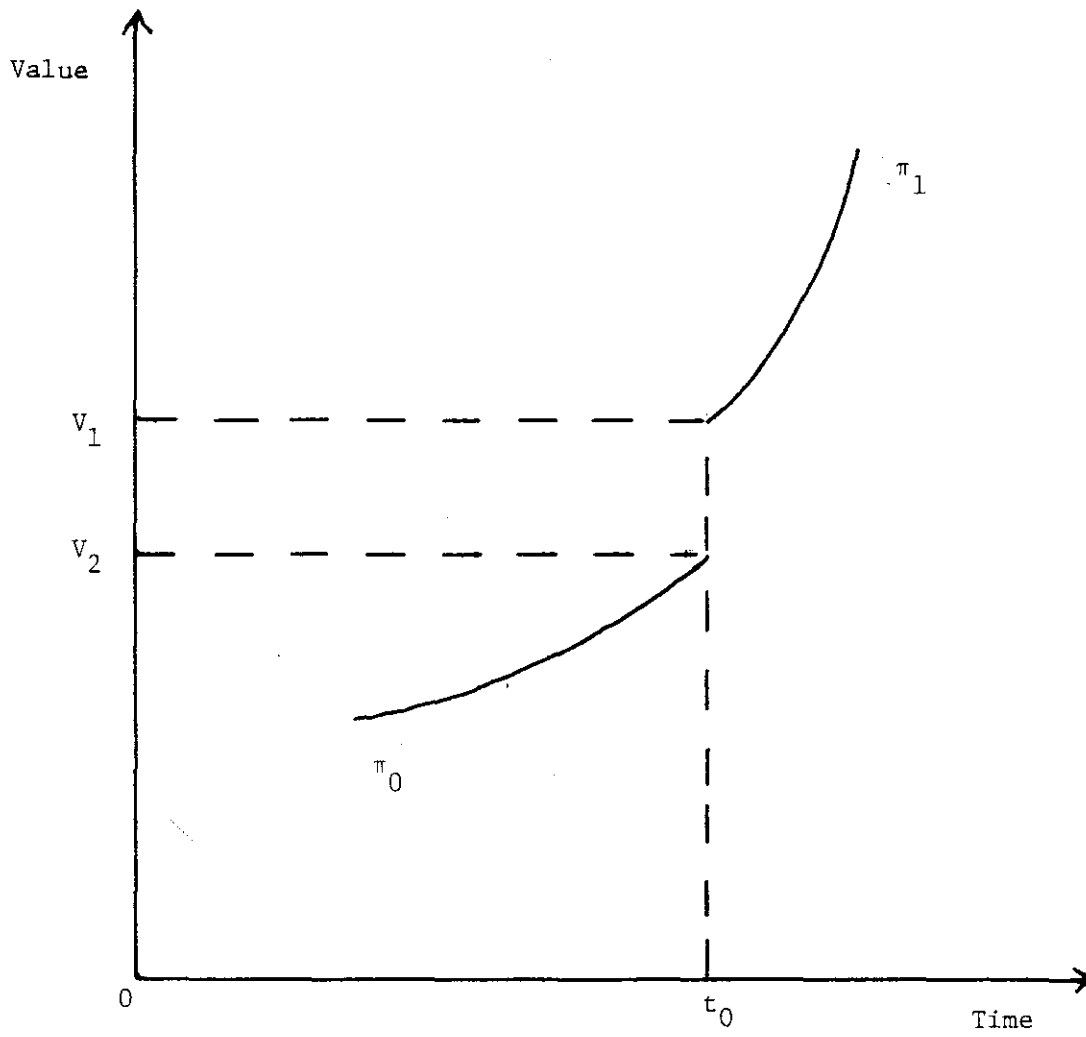


Figure 1. The Time Path of Land Values with an Increase in Inflation

An adaptive model was used to provide an initial specification of the expected inflation rate. Under Feldstein's hypothesis, the relevant level of inflation is that prevailing throughout the entire life of the asset. An adaptive specification is designed to generate only point forecasts, rather than estimates of inflation over an extended period. Thus, it cannot be expected to provide the relevant forecast, unless land purchasers form expectations of future inflation in a "naive" manner.

Another estimate of inflationary expectations was derived by subtracting an average "real" interest rate over the sample period from a long term interest rate. This approach assumes that the real interest rate is approximately constant and that nominal interest rates contain information about future rates of inflation. This use of interest rates is consistent with the rational expectations hypothesis that market participants form expectations of inflation which are unbiased estimates of the true value given the information available at the time.

Some empirical evidence for this approach is provided in a study conducted by Fama. In this study, he was unable to reject the hypothesis of a constant real rate of interest and concluded (p. 269) that the bill market was efficient in the sense that "nominal interest rates summarize all the information about future inflation rates that is in time series of past inflation rates." Shiller (p. 155) also notes a close correspondence between nominal interest rates and optimally forecasted inflation rates after 1951.

DATA

A brief description of each original variable and the details of its source is given in Appendix 1. The data used are the recently revised USDA series recommended by Melichar (1981, p. 735). The data were available from 1940-1979 but the wartime years prior to 1946 were not included in the analysis because of possible differences in investor behavior. The forty years of data available were adequate for econometric analysis but not really sufficient for Box-Jenkins time-series procedures.

Data on the value of Farm Real Estate, including land and fixed structures, provided the dependent variable in the econometric analysis. Although data on the value of land alone would have been preferred, no such disaggregated data series appeared to be available. In any event, it seems a reasonable approximation to treat land and durable structures together. The value of the operator's dwelling and of other assets not used to generate farm income was excluded from this variable.

No estimate of the return to Farm Real Estate was available directly. This variable was estimated by allocating the Residual Income to Production Assets (USDA, 1980, p. 53) in proportion to the value of real estate and other capital. While this procedure is somewhat arbitrary, some adjustment was essential because the share of real estate in total production assets increased from 70.2 percent in 1946 to 79.2 percent in 1979 (Hottel and Evans, p. 63). This procedure was preferred

to the alternative of deducting a specified rate of return to nonland assets (Hauschen and Herr) because of the difficulty in obtaining a suitable rate of return and because the subtraction approach concentrates all the error in the residual return to land.

Two, possibly offsetting, sources of bias can be expected in the adjustment procedure used to derive the return to Farm Real Estate. Because of the growth in real estate returns, purchasers may be willing to accept a lower rate of return on land than on other assets (Melichar). Because of the fixed nature of many nonland inputs, their opportunity cost estimates may have overestimated the returns to these inputs in the time period considered (Tweeten, p. 181). This first bias would cause the measured variable to over-estimate the net returns to real estate while the second would cause it to under-estimate this net return.

The Implicit Price Deflator for GNP was chosen as a suitably broad measure of price changes. Estimates of the annual inflation rate were calculated using this variable. This variable was also used to deflate net returns when calculating the real growth rate of returns and the moving variance of net returns.

The interest rate on long-term Treasury Bonds was used to provide a predictor of inflation into the future. This interest rate is not completely suitable because the ten year maturity used may be shorter than the time horizon of land market participants. However, longer term rates do not appear to differ greatly from these values.

The notation and description of all variables actually appearing in the analysis are given in Table 1.

Table 1. Variables appearing in the Analysis

FRE = the total value of farm real estate, Feb. 1 (\$ billion).

GR = the real percentage growth rate in net returns to FRE.

NR = the residual net return to farm real estate (\$ billion).

PI = the annual percentage rate of inflation in the implicit price deflator for GNP.

PIE = the expected percentage rate of inflation estimated from long term Treasury Bonds.

VAR = the three year moving variance in real residual net returns (for years t-1, t-2, t-3).

VYL = the ratio of real estate value to net returns in the previous year
 $(\text{FRE}_t / \text{NR}_{t-1})$

Before proceeding to the statistical estimation it will be worthwhile to look at a plot of the data. Figure 2 includes a plot of the ratio of FRE to NR (denoted VY) for each year and also the actual rate of inflation in each year. While the plot of VY is very erratic because of the wide year to year variability in returns, some trends seem to be evident. VY appears to have been generally increasing between 1946 and 1960 during which period inflation stabilised, and possibly declined. Between 1960 and 1972, the trend in VY appears to have been downward

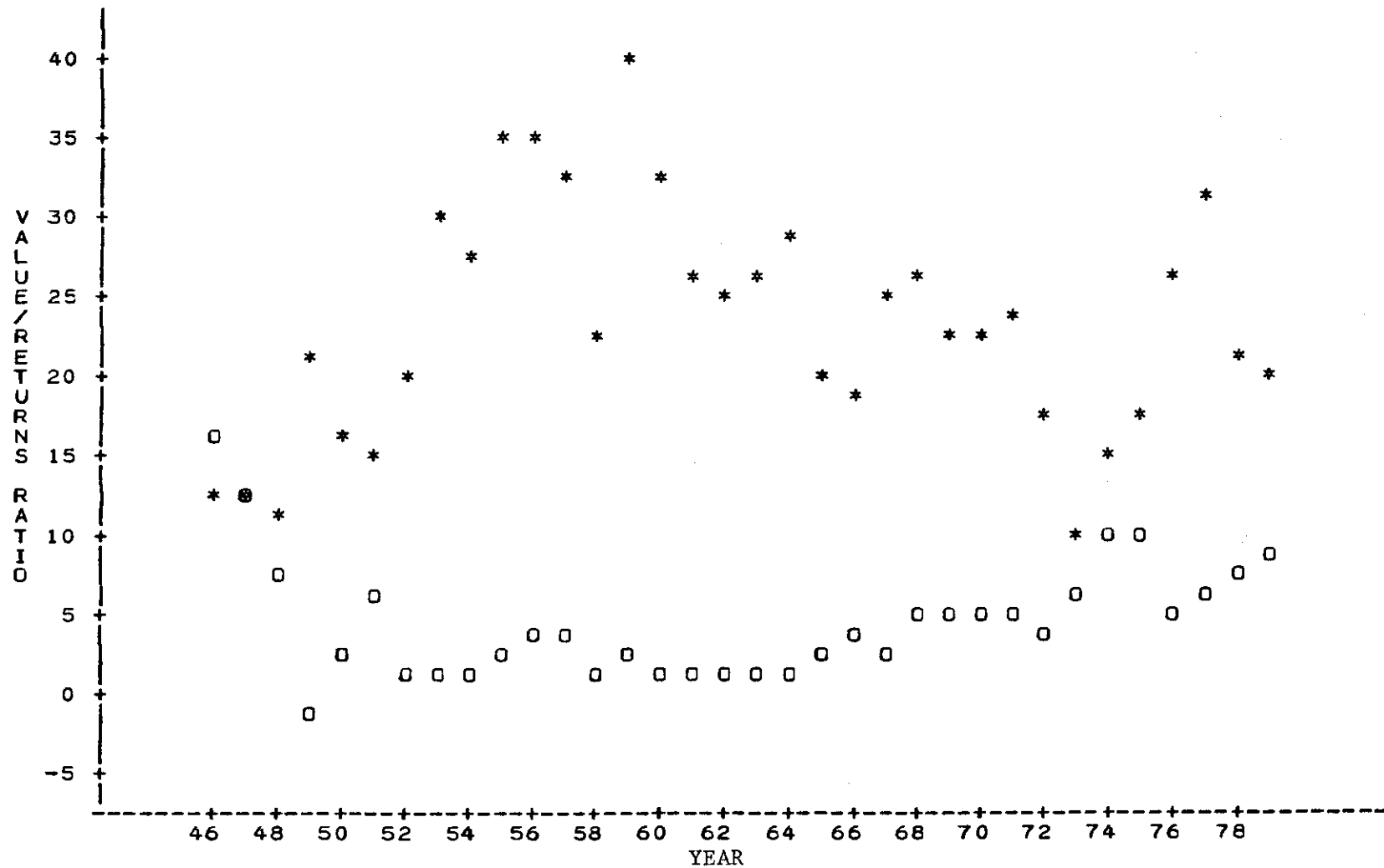


Figure 2. Plot of Value/Net Returns Ratio and the Inflation Rate by Year, 1946-1979*

* - Denotes the ratio of the value of Farm Real Estate to its Net Return (FRE/NR)

o - Denotes the percentage of change in the Implicit Price Deflator for GNP

while the trend in inflation was steadily upward. During the remainder of the 1970s, the trend in both inflation and VY was upwards. Clearly, casual examination of the data provides neither strong support, nor strong contrary evidence, for the hypothesis so we now turn to the statistical analysis.

ESTIMATION AND RESULTS

Some initial estimates of the impact of inflation on farm real estate value were made using the ratio of FRE to net returns, NR, in the previous year (VYL) as the dependent variable. While this method provides a direct test of the hypothesis that inflation influences the real value of farm real estate, it does not explicitly incorporate the generation of expectations about future returns. The extreme year to year variation in returns also causes many of these models to have low explanatory power. As a result, the remainder of the analysis was undertaken using the nominal value of Farm Real Estate as the dependent variable and explicitly incorporating expectations about returns and other variables. Expected returns were included in all the estimated equations of this type and other variables were then included as shifters of the value/expected returns relationship.

In most cases, expectations about the future values of variables were assumed to be formed according to an adaptive process. Since such expected values are unobservable, it was necessary to transform the equations in which they appeared to obtain forms in observable variables. This was done using the Koyck transformation (Johnston, p. 198).

Unfortunately, this transformation leads to estimation forms in which the error terms are autocorrelated and in which the lagged dependent variables are correlated with the error term. The correlation between explanatory variables and the error term causes biased parameter estimates even in large samples (Johnston, p. 307). While autocorrelated errors by themselves do not bias the parameter estimates, they make the use of ordinary least square (OLS) less efficient. In addition, OLS procedures are likely to seriously underestimate sampling variances and as a consequence, to bias hypothesis tests in favor of rejecting the null hypothesis.³ The combination of autocorrelated errors and correlation between explanatory variables and the error term poses serious estimation problems.

In a few simple cases, it was possible to consistently estimate parameters by OLS. However, in most cases, the equations contained lagged dependent variables and so alternative procedures were required. In a few equations, a 2SLS procedure described by Judge et al (p. 666) was used. In this approach, the problem of correlation between the lagged dependent variables and the error terms is overcome by replacing the lagged dependent variables with their predicted values obtained using lagged values of other explanatory variables.⁴ This estimation procedure should produce consistent parameter estimates but is inefficient since it ignores information obtainable from the structure

of the error terms. Most of the estimates were obtained using an extension of this procedure which allowed for autocorrelation in the residuals. All of the equations were estimated in linear form which provides a Taylor Series approximation to potentially more complex structures.

Five simple equations are presented in Table 2. Since PIE and VAR are assumed to represent exactly the expectation held in the market about future inflation and variability in returns, the first three equations do not require transformation to take account of expectations.

Equation 2.1 expresses VYL as a function simply of expected inflation. This equation has extremely low explanatory power and the DW statistic suggests positive autocorrelation of the residuals, presumably due to the omission of relevant explanatory variables. Although the variance estimates are likely to be biased downwards in this equation and hypothesis tests thus biased against the null hypothesis, the coefficient estimate for expected inflation is clearly not significantly greater than zero.

Equation 2.2 and 2.3 contain the same explanatory variables and differ only in the estimation technique used. In each case, the expected inflation rate has the expected positive sign and the variance term has the negative sign expected from the assumption of risk aversion. While the coefficient on PIE is close to significance at the 10 percent level in Equation 2.2, this may be a function primarily of

Table 2. Estimated Equations for the Ratio of Real Estate Value to Returns*

2.1	$\text{VYL}_t = 23.75 + 0.29 \cdot \text{PIE}_{t-1} \quad (R^2 = 0.004,$ $(8.27) \quad (0.38)$ $\text{DW} = 0.75; \text{DF} = 32; \text{OLS})$
2.2	$\text{VYL}_t = 22.59 + 1.20 \cdot \text{PIE}_{t-1} - 3426.2 \cdot \text{VAR}_t$ $(8.65) \quad (1.59) \quad (-2.93)$ $(R^2 = 0.22; \text{DW} = 0.94; \text{DF} = 31; \text{OLS})$
2.3	$\text{VYL}_t = 23.31 + 0.44 \cdot \text{PIE}_{t-1} - 341.25 \cdot \text{VAR}_t$ $(5.05) \quad (0.36) \quad (-0.30)$ $(R^2 = .006; p_1 = -0.55; \text{DF} = 31)$
2.4	$\text{VYL}_t = 11.77 - 0.80 \cdot \text{PI}_{t-1} - 2259.27 \cdot \text{VAR}_t + 2679.4 \cdot \text{VAR}_{t-1}$ $(1.55) \quad (-2.63) \quad (-2.27) \quad (2.25)$ $+ 0.66 \cdot \text{VYL}_{t-1} \quad (R^2 = 0.50; \text{DW} = 2.57; \text{DF} = 28, \text{DH} = -0.51; \text{2SLS})$ (2.43)
2.5	$\text{VYL}_t = 8.49 + 2.44 \cdot \text{PIE}_{t-1} - 2.03 \cdot \text{PIE}_{t-2} + 300.6 \cdot \text{VAR}_t$ $(2.12) \quad (1.42) \quad (-1.15) \quad (0.34)$ $-1432.26 \text{VAR}_{t-1} - 0.16 \cdot \text{GR}_{t-1} + 0.66 \cdot \text{VYL}_{t-1}$ $(-1.88) \quad (-6.24) \quad (3.81)$ $(R^2 = 0.76; \text{DW} = 1.25; \text{DF} = 26; \text{DH not defined})$

*Numbers in parentheses under the coefficient estimates are t-statistics for $H_0: b = 0$. After each equation the R^2 as output by the computer program is given with the Durbin-Watson statistic (DW) and the method of estimation (OLS = Ordinary Least Squares. ALS = Autoregressive Least Squares. 2SLS = Two Stage Least Squares). p_1 = Estimated First Order autoregressive parameters where data transformed $(X_t - p_1 X_{t-1})$ have independent errors, DH = Durbin's h statistic.

the estimation procedure used. The DW statistic in 2.2 suggests positive autocorrelation and, after correction for this in 2.3, neither explanatory variable appears to be significant.

Equation 2.4 is the first equation to incorporate adaptive expectations on the explanatory variables and is thus worthy of additional comment. It is derived from the model:

$$(7) \quad VYL_t = a + b PI_t^* + c VAR_{t-1} + e_t$$

where

$$(8) \quad (PI_t^* - PI_{t-1}^*) = m (PI_{t-1} - PI_{t-1}^*)$$

and $0 \leq m \leq 1$

Rewriting (8) in terms of the backshift operator (Sargent, p. 171), we obtain:

$$(1-(1-m)B)PI_t^* = m.PI_{t-1}$$

and thus

$$(9) \quad PI_t^* = \frac{m.PI_{t-1}}{(1-(1-m)B)}$$

Substituting (9) into (7) and cross multiplying yields:

$$(10) \quad (1-(1-m)B)VYL_t = a.m + b.m.PI_{t-1} + c.VAR_{t-1} \\ - c(1-m).VAR_{t-2} + e_t - (1-m)e_{t-1}$$

Equation (10) illustrates an important property of the Koyck transformation. If the original error term in the model was independently distributed, then the new error term will follow an MA(1) process. If the original error term was autoregressive, the new error term will follow a more complex ARMA process.⁵ Since,

the error structure was unknown, initial estimates were obtained by the 2SLS procedure assuming that the errors were approximately independent.

In equation 2.4, the coefficient of PI_{t-1} is an estimate of the product $b \cdot m$ and thus depends upon both the adjustment parameter, m , which is hypothesized to be between zero and one, and the impact multiplier of anticipated inflation, b , which is hypothesized to be positive. The estimated coefficient is actually negative and would be significantly different from zero if a two tailed test were applied. This equation thus provides some tentative evidence against Feldstein's hypothesis, if expectations are formed adaptively. The moving variance term has the negative coefficient expected under the assumption of risk aversion.

Equation 2.5 incorporates the assumption that changes in inflationary expectations are represented by changes in the inflation premium on Treasury Bonds. Expectations of the real growth rate of returns are assumed to be formed adaptively and the equation is then transformed as for equation 2.4. The coefficient on the expected inflation rate, PIE , has a positive sign but is not significantly different from zero. The coefficient on VAR_{t-1} is not significant and is of the "wrong" sign. The growth rate term also has an incorrect sign under the adaptive expectations hypothesis. However, the negative sign on GR is not entirely unexpected since the

value of the lagged returns appears in the denominator and thus directly effects the dependent variable. Clearly, any effect of an increase in returns on expected growth rates and hence asset value is dominated in the short run by this direct effect.

Clearly, Equations 2.1 and 2.5 provide very little evidence in favor of Feldstein's hypothesis. Even though the tests are probably biased towards rejection of the null hypothesis in each equation except 2.3, the coefficient for expected inflation is not significant in any case. If inflationary expectations were formed adaptively, equation 2.4 would suggest a negative effect on real estate value.

We now turn to equations for FRE which incorporate the formulation of expectations about future returns. The final set of estimates of these equations is presented in Table 3. These estimates were derived by applying a correction for autocorrelation in the second stage of 2SLS.⁶ Both first and second order autoregressive terms were allowed for in the estimation process as an approximation to more complex ARMA processes. Because predicted values, rather than actual values, of the lagged dependent variables were used in the second stage, the estimates of the autoregressive parameters may be biased to some degree. The method will yield consistent parameters of the other parameters and these should be more efficient than those obtained from 2SLS procedures as long as the bias in the autoregressive parameter estimates is not too large.

A number of alternative methods of estimation have been suggested for estimation with lagged dependent variables

(eg Fuller, p 445) and a number of these were investigated. Where the error term can be realistically be approximated by an autoregressive process, nonlinear estimation procedures allow the correlation between error and explanatory variable to be removed by substituting for the lagged errors. When such procedures were investigated, the resulting models frequently degenerated into extrapolative forms in which the lagged dependent had a coefficient in excess of one. It was believed that remaining correlation between the unaccounted for error components and the explanatory variables may have biased the coefficients in these models. To avoid this problem, the predicted values of the lagged dependent variable were used in all the equations for which results are presented.

Seven equations estimating the relationship between FRE, expected net returns and other explanatory variables are presented in Table 3.

Equation 3.1 in Table 3 is derived from the model:

$$(11) \quad FRE_t = a + bNR_t^* + e_t \dots$$

where expectations are formed according to the adaptive process:

$$(12) \quad (NR_t^* - NR_{t-1}^*) = m(NR_{t-1} - NR_{t-1}^*) \text{ and} \\ 0 \leq m \leq 1$$

The model (11) contains the unobservable variable NR_t^* . The details of the transformation of models (11) and (12) into the estimation form of Equation 3.1 are given in Appendix 2.

This equation appears to fit the data quite well. The insignificant⁷ intercept term is consistent with a capital budgeting model such as that given in (3). Equation 3.1 can be solved for the expectation adjustment parameter, m , and for the implied long-run relationship between land values and the return from land. A value of 0.34 is obtained for the adjustment parameter. This implies that the mean lag in adjusting expectations of the nominal net return to land is 2 years⁸ (Johnston, p. 299). In the long run,⁹ this equation implies an FRE/NR ratio of 22.9, or a rate of return of 4.4 percent.

Equation 3.2 was also derived from Model (11) but in the case where expectations are formed by an adaptive process with trend, such as:

$$(13) \quad (NR^*_t - NR^*_{t-1}) = m(NR_{t-1} - NR^*_{t-1}) + GR^*_t$$

$$(14) \quad (GR^*_t - GR^*_{t-1}) = p(NR_{t-1} - NR^*_{t-1})$$

$$(15) \quad GR_t = NR_t - NR_{t-1} \text{ and } GR^*_t = NR^*_t - NR_{t-1}$$

where $0 \leq m, p \leq 1$

The estimated equation appears to fit the data very well when plotted and has a reasonably high R^2 value. Unfortunately, the equation does not seem to be consistent with the postulated expectation adjustment mechanism. When the equation is solved for

Table 3. Estimated Equations for Farm Real Estate Value¹

-
- 3.1 $FRE_t = 9.9 + 7.73NR_{t-1} + 0.66FRE_{t-1}$ ($R^2 = 0.83$, $p_1 = 0.51$,
 (0.89) (7.30) (10.72) (3.45)
 1946-79, DF=31)
- 3.2 $FRE_t = -17.3 + 6.54NR_{t-1} - 3.33NR_{t-2} + 0.52FRE_{t-1} + 0.49FRE_{t-2}$
 (-1.32) (6.43) (-2.13) (5.39) (6.86)
 ($R^2 = 0.89$, $p_1 = 0.44$, $p_2 = 0.25$, 1946-79, DF=28)
 (2.58) (1.52)
- 3.3 $FRE_t = -0.13 + 4.89NR_{t-1} - 9300VAR_{t-1} + 8020VAR_{t-2}$
 (-0.02) (7.57) (-4.20) (3.89)
 + $0.86FRE_{t-1}$ ($R^2 = 0.92$, $p_1 = 0.40$, 1948-79, DF = 26)
 (21.22) (2.40)
- 3.4 $FRE_t = -8.37 + 7.80NR_{t-1} - 4.65NR_{t-2} - 0.19GR_{t-1} - 0.021GR_{t-2}$
 (-0.64) (4.42) (-2.00) (-1.07) (-0.15)
 + $0.59FRE_{t-1} + 0.41FRE_{t-2}$ ($R^2 = 0.92$, $p_1 = 0.59$,
 (6.32) (5.29) (4.16)
 1947-79, DF=26)
- 3.5. $FRE_t = -3.39 + 6.69NR_{t-1} - 3.34NR_{t-2} - 2.27PI_{t-1} + 0.46PI_{t-2}$
 (-0.29) (5.86) (-3.84) (-2.61) (0.34)
 + $0.53FRE_{t-1} + 0.48FRE_{t-2}$ ($R^2 = 0.94$, $p_1 = 0.32$,
 (4.84) (6.19) (1.91)
 $p_2 = 0.11$, 1947-79, DF=26)
 (0.67)
- 3.6 $FRE_t = -8.87 + 4.53NR_{t-1} + 19.0PIE_{t-1} - 11.17PIE_{t-2} + 0.75FRE_{t-1}$
 (-0.88) (4.33) (2.12) (-1.13) (7.94)
 $R^2 = 0.92$, $p_1 = 0.32$, 1946-79, DF=29)
 (1.95)

Table 3. (continued)

$$3.7 \quad \text{FRE}_t = 0.36 + 3.45\text{NR}_{t-1} - 7792\text{VAR}_{t-1} + 9472\text{VAR}_{t-2} + 7.48\text{PIE}_{t-1}$$

$$\quad \quad (0.54) \quad (4.00) \quad (-2.74) \quad (3.24) \quad (0.90)$$

$$\quad \quad - 9.15 \text{PIE}_{t-2} + 0.93\text{FRE}_{t-1} \quad (R^2 = 0.97, p_1 = 0,$$

$$\quad \quad (-1.14) \quad (13.95)$$

1949-79, DF=24)

¹Figures in parentheses are t-statistics for $H_0: b_i = 0$. These were calculated using the error variance calculated with the actual values of the lagged dependent variables in the equation.

R^2 is as output from the regression program for the transformed variables eg $(X_t - p_1 X_{t-1})$.

p_i = ith order Autoregressive Parameter eg $u_t = \sum_{i=1}^n p_i \cdot u_{t-i} + e_t$
 where n is the order of the autoregressive process.

DF = Degrees of freedom for the regression

the values of m and p , the estimates obtained lie outside the range of zero to one. In addition, solving the equation for a long-run relationship between NR and FRE produced infeasible results. While this equation may provide a useful "time-series" prediction model for the value of Farm Real Estate, it does not appear to be consistent with the postulated expectation formation mechanism.

The apparent failure of the adaptive expectations model with trend to capture the process of formation of expectations about returns to land contrasts with the success which Jacobs and Jones experienced in modeling explicit price expectations. It raises serious questions for research into the appropriate process of expectation formation in this market, since a single adaptive model produces biased estimates where the data contain a trend. If market participants do, in fact, form their expectations in this way, then some information is being wasted.

The remaining equations to be considered in this paper assume that expectations about returns are formed by a simple adaptive process. This approach follows from the results obtained in Equations 3.1 and 3.2.

Equation 3.3 includes both the expected Net Returns variable and a moving-variance variable to reflect perceived uncertainty in the returns to farm real estate. The underlying model is the linear form:

$$(16) \text{FRE}_t = a + b.NR*_t + c.VAR_{t-1} + e_t$$

The details of the transformation of this model into the estimation form used in Equation 3.3 are given in Appendix 2.

In evaluating Equation 3.3 most interest focuses on the coefficient of VAR_{t-1} . This coefficient corresponds to c in Model (16). It has the hypothesized negative sign and is significantly lower than zero at the usual 5 percent level of significance. The negative sign of this coefficient is consistent with risk aversion by participants in the real estate market. The overall degree of explanatory power achieved by this equation ($R^2 = 0.92$) was higher than in either of the previous equations. The results of this equation suggest that risk attitudes are quite important since a three year moving variance term is a somewhat arbitrary measure of the expected variance in net returns.

Given the importance attached to the expected growth rate of net returns by authors such as Melichar, it seemed necessary to consider this factor in any analysis of real estate values. Equation 3.4 was derived from an adaptive model in which expectations of both Net Returns and the real Growth Rate of Net Returns are formed by adaptive processes. The model underlying this equation was the linear form:

$$(17) \quad FRE_t = a + b.NR*_t + c.GR*_t + e_t$$

where expectations of NR and GR are formed by adaptive processes with different adaptive parameters, as in;

$$(18) \quad (NR*_t - NR*_{t-1}) = m(NR_{t-1} - NR*_{t-1})$$

$$(19) \quad (GR*_t - GR*_{t-1}) = n(GR_{t-1} - GR*_{t-1})$$

The details of the transformation from models (17), (18), (19) into the estimation form for Equation 3.4 are given in Appendix 2.

In interpreting Equation 3.4, most attention focuses on the coefficient of GR_{t-1} . In terms of the parameters of the original model, this coefficient equals the product $c \cdot n$. The estimate of this coefficient in Equation 3.4 is not significantly different from zero and is negative in sign. For this coefficient to be zero requires that either c equals zero or n equals zero or that both equal zero. If c equals zero, land market participants do not react to changes in the growth rates of return. If n equals zero, expectations of growth rates are never revised. In either case, a zero value implies that changes in expected growth rates do not affect the value of farm real estate. Our results thus suggest that changes in the growth rate of expected net returns have not played a significant role in changes in the value of farm real estate. As a result, this term was omitted from subsequent equations.

A plot of the real growth rate of returns indicated a great deal of variability about a mean of 6.86 percent but no sustained trends. While the theory discussed in the first part of this paper suggests that expectations of growth should influence the price of farm real estate, it appears from these results that changes in these expectations have not contributed greatly to changes in farm real estate prices since 1947. However, expectations of growth in returns may still have influenced the price of land throughout the entire period.

Expectations of inflation are introduced in Equation 3.5. This equation is based upon the model:

$$(20) \text{FRE}_t = a + b.NR^*_t + c.PI^*_t + e_t$$

Expectations of net returns and the inflation rate are formed adaptively with different adjustment parameters, as in Equation 3.4. In evaluating the results of Equation 3.4, the coefficient of the variable PI_{t-1} is crucial. This variable represents the product $c.n$ in terms of the parameters of the original model. Since n lies between zero and one under the adaptive expectations hypothesis, the sign of this coefficient was hypothesized to be positive. The estimated coefficient was actually negative, contrary to our hypothesis, but consistent with the result obtained in Equation 2.4.

The results obtained in Equation 3.5 may arise because inflationary expectations are not formed adaptively. Inflationary expectations over the entire lifetime of the asset are relevant to Feldstein's hypothesis and not merely the point forecasts obtained from an adaptive process. On the assumption that inflationary expectations are not formed adaptively, Equations 3.6 and 3.7 utilize the variable PIE reflecting expectations of inflation derived from the inflation premium on Treasury Bonds.

Equation 3.6 is derived from the model:

$$(21) \quad \text{FRE}_t = a + b.\text{NR}_t^* + c.\text{PIE}_{t-1} + e_t$$

Expectations of net returns, NR_t^* , are again assumed to be formed adaptively and the derivation of the form used for estimation follows that of Equation 3.3.

The coefficient of PIE_{t-1} in Equation 3.6 is an estimate of the effects of inflation corresponding to c in model (17). This coefficient has the hypothesized positive sign, is plausible in magnitude and is significantly greater than zero at the 5 percent level (one tailed test). While this equation on its own would suggest rejection of the null hypothesis, it must be remembered that the procedure used represents only a very approximate correction for autocorrelation and so the sampling variances may well be underestimated.

Equation 3.6 does not include the variance term which was found to be significant in Equation 3.3. Since the variability of net returns was higher during the 1970s when the inflation rate was also high, it was felt possible that the omission of a variable to account for risk may have biased the coefficient on inflationary expectations. Accordingly the model (21) was modified by adding the three year moving variance term used in Equation 3.3. This yielded the more complete model:

$$(22) \quad \text{FRE}_t = a + v.\text{NR}_t^* + c.\text{PIE}_{t-1} + d.\text{VAR}_{t-1} + e_t$$

Model (22) was transformed into observable form by applying the same transformation as was previously applied to Model (16). The results of the estimation are presented as Equation 3.7 in Table 3. The coefficient of PIE_{t-1} is an estimate of the coefficient c in Model 18. As in Equation 3.6, the estimated value of c is positive and plausible in magnitude. However, it is clearly not significantly different from zero. Thus, the full model does not provide any evidence that the effect of expected inflation differs significantly from zero.

Clearly, the results obtained from the twelve equations considered are somewhat mixed. The weight of evidence suggests that a simple adaptive mechanism is a reasonable specification of the formation of expectations about net returns. Equally clearly, the evidence suggests that expectations about the growth rate of returns and of inflation cannot be represented adequately by an adaptive process. The moving variance of returns had the negative sign expected under the assumption of risk aversion and was generally significant.

The variable for expectations of inflation derived from the interest rate on Treasury Bonds had the expected positive coefficient in all of the six equations in which it appeared. However, it was significantly greater than zero in only one case (Equation 3.6) even though the hypothesis tests may well have been biased in favor of rejecting the null hypothesis. Thus, none of the evidence reviewed suggests that inflationary expectations have had a major impact on the determination of farm real estate values during the period considered.

SUMMARY AND CONCLUSIONS

In this paper, we set out to test Feldstein's hypothesis that changes in the expected rate of inflation should affect the real value of farm real estate. Visual inspection of the data did not reveal strong evidence of such a relationship and a number of reduced form econometric models were formulated to test the hypothesis.

Five equations were estimated with the ratio of Real Estate Value to Net Returns in the previous year as the dependent variable. In these equations, the measure of inflationary expectations derived from the long-term bond rate had the expected positive sign but was not significant. When inflationary expectations were postulated to be formed by an adaptive process, the resulting equation had a negative and apparently significant coefficient.

In order to incorporate expectations about net returns, seven equations were estimated with the total value of Farm Real Estate as the dependent variable. Within this group of equations, the simple adaptive expectations hypothesis appeared to perform quite well in relating farm real estate value to net returns. In most cases, it yielded highly significant coefficients and plausible parameter estimates as well as providing a high degree of explanatory power.

The hypothesis that expectations could be represented by a more sophisticated adaptive process with trend was also considered. The parameters derived from the estimated equation were, however,

inconsistent with the hypothesis. The result may merely be due to the characteristics of the particular data set used and this hypothesis seems worthy of further investigation given its success in representing general price expectations (Jacobs and Jones).

The variability of net returns was represented by a three year moving variance term. This variable had the expected negative sign and was significant in most of the equations in which it was included.

From theory, the expected growth rate of net returns to real estate seems likely to influence its value. The growth rate variable used was based on the assumption that expectations are formed adaptively. Under this assumption, we were unable to establish a positive relationship between expected growth rate in real returns and changes in real estate values.

The use of simple adaptively formed expectations of future inflation yielded negative coefficients in both of the equations in which they were included. In one case, the coefficient was significantly lower than zero. There is no obvious rationale for a negative coefficient on expected inflation and so these results suggest that simple adaptive expectations do not appropriately represent the formation of inflationary expectations.

A "rational" estimate of inflationary expectations derived from long term bond rates produced a positive coefficient in all six equations in which it was included. However, it was significantly different from zero in only one of these equations.

Overall, from the evidence considered, it does not appear that inflationary expectations have had a major, direct impact on the value of U.S. Farm Real Estate. Only a highly tentative link has been established between the inflation premium in bond rates and farm real estate value. The only clear conclusion seems to be that expectations of inflation are not formed adaptively if either Feldstein's hypothesis or the conventional neutrality assumption are correct.

A great deal of further analysis will be needed before the effects of inflation on asset markets such as this one are adequately understood. For instance, at the state or regional level, it may be possible to obtain data relating to a much more homogeneous input than the aggregate of U.S. Farm Real Estate. Regional or state level studies may thus be able to discern value responses which are not evident in the national data. Techniques such as causality analysis may be useful in investigating the time pattern of any relationship between asset values and inflation. Investigation of particular sub-periods might also be worthwhile if it is believed that the process of formulating expectations has changed over time or other important structural factors such as Federal Reserve policy have changed. Hopefully, this paper has presented some initial evidence and approaches which will be useful in subsequent work.

FOOTNOTES

1. They are actually value functions since the dependent variable is the value of farm real estate. Since the supply of farm real estate is very slow to change, changes in the dependent variable are largely due to changes in price.
2. It is possible that they would have another impact by reducing uncertainty but in any event, this effect would not be captured by the variables specified in previous models.
3. The bias is negative in the common case of first order positive autocorrelation in the errors with positive autocorrelation in the explanatory variables. The nature and extent of the bias depends upon the type of autocorrelation and the magnitude of its parameters (Judge et al., p. 178).
4. The expected value of FRE_t was estimated as a function of the independent variables in the equation lagged one, two, and three years. These variables were then lagged to the extent necessary in the equation being estimated.
5. Since any invertible M.A. process can be converted into an infinite autoregressive (A.R.) process with declining weights, the use of conventional autoregressive procedures should be an improvement over the assumption of independent errors. Only autoregressive transformation procedures were considered in this analysis.

6. This procedure was suggested by Barr et al. (p. 133). A revision was needed to obtain an appropriate estimator of the disturbance variance and hence of the parameter sampling variances. To do this, the estimated errors were recalculated using the actual value of the lagged dependent variables, rather than their predicted values.
7. The intercept was not restricted to zero since its value approached economic insignificance by comparison with the 1979 FRE value of \$545.6 billion.
8. The actual estimate was 1.96 years.
9. In the "long run" $FRE_t = FRE_{t-1}$ and equation was solved using this substitution.

REFERENCES

- Barr, A. J. et al. "SAS User's Guide, 1979 Edn., SAS Institute, P.O. Box 8000, Cary, NC, 1979.
- Brown, W. W. and G. J. Santoni. "Unreal Estimates of the Real Rate of Interest," Federal Reserve Bank of St. Louis Review 63(1):18-26, 1981.
- Bureau of Economic Analysis. The Survey of Current Business, U.S. Dept. of Commerce, Washington, D.C., January (see also October, 1978 edn.), 1980a.
- Bureau of Economic Analysis. Business Conditions Digest, U.S. Gov't. Printing Office, Washington, D.C., November 1980b.
- Evans, C. D. Balance Sheet of the Farming Sector, 1979 - Supplement to AIB No. 430, United States Dept. of Agriculture, Washington, D.C., 1980.
- Fama, E. F. "Short term Interest Rates as Predictors of Inflation" American Economic Review LXV(3) June, pp. 269-282, June 1975.
- Feldstein, M. "Inflation, Tax Rules, and the Prices of Land and Gold" Journal of Public Economics, December 1980a.
- Feldstein, M. "Inflation, Portfolio Choice, and the Prices of Land and Corporate Stock" American Journal Agricultural Economics 62(5):910-916, 1980b.
- Feldstein, M. "Inflation, Tax Rules and the Stock Market" Journal of Monetary Economics 6(3):309-331, 1980c.

- Fuller, W. A. Introduction to Statistical Time Series, John Wiley & Sons, New York, 1976.
- Hauschen, L. D. and W. M. D. Herr "A New Look at the Relationship Between Farm Real Estate Prices and Expected Returns to Land," Paper presented to 1980 American Agricultural Economics Association Conference, Urbana-Champaign, 1980.
- Hottel, J. B. and C. D. Evans. "Returns to Equity Capital in the U.S. Farm Production Sector," in C. D. Evans, Balance Sheet of the Farming Sector, 1979, Supplement, Agricultural Information Bulletin No. 430, U.S. Dept. of Agriculture, Washington, D.C., 1980.
- Jacobs, R. L. and R. A. Jones. "Price Expectations in the United States, 1947-75" American Economic Review 70(3):269-277, 1980.
- Johnston, J. Econometric Methods 2nd. Edition McGraw Hill, New York, 1972.
- Judge, G.G., W. E. Griffiths, R. Carter-Hill, and T. C. Lee. The Theory and Practice of Econometrics, John Wiley, New York, 1980.
- Klinefelter, D. A. "Factors Affecting Farmland Values in Illinois," Illinois Agricultural Economics January pp. 27-33, 1973.
- Kreicher, L. L. "An International Evaluation of the Fisher Hypothesis Using Rational Expectations," Southern Economic Journal 48(1):58-67, 1981.
- Melichar, E. "Capital Gains versus Current Income in the Farming Sector" American Journal of Agricultural Economics 61(5), 1979.

- Melichar, E. "Capital Gains versus Current Income in the Farming Sector:Reply" American Journal of Agricultural Economics 63(4):734-737, 1981.
- Nelson, E. "Rational Expectations and the Estimation of Econometric Models" International Economic Review 16(3), October 1975.
- Plaxico, J. S. and D. D. Kletke "The Value of Unrealized Farm Land Capital Gains" American Journal of Agricultural Economics 63(2):283-284, 1981.
- Pope, R. D. , R. A. Kramer, R. D. Green, and B. D. Gardner. "An Evaluation of Econometric Models of U.S. Farmland Prices," Western Journal of Agricultural Economics, pp. 107-119, July 1979.
- Sargent, T. J. Macroeconomic Theory, Academic Press, New York.
- Shiller, R. J. "Can the Fed Control Real Interest Rates?" in Fischer, S. ed. (1980) Rational Expectations and Economic Policy, University of Chicago Press, Chicago.
- Tweeten, L. Foundations of Farm Policy, University of Nebraska Press, Lincoln, Nebraska, 1979.
- Tweeten, L. "Macroeconomics in Crisis: Agriculture in an Under-achieving Economy," American Journal of Agricultural Economics 62(5):853-865, 1980.
- U.S. Department of Agriculture. "Farm Income Concepts: Their Meaning and Measurement" in Farm Income Situation FIS-224. ESCS, U.S.D.A., Washington, D.C., pp. 74-75, 1974.

U.S. Department of Agriculture. Economic Indicators of the Farm Sector

Statistical Bulletin 650, U.S.D.A., Washington, D.C., 1980.

U.S. Treasury Dept. Treasury Bulletin, June, U.S. Gov't Printing

Office, Washington, D.C., 1965.

APPENDIX 1: SOURCES AND DESCRIPTION OF THE INPUT DATA SET

1. Farm Real Estate Value (FRE) - (Hottel and Evans, p. 63, col A).
As of February 1; Total market value of U.S. farmland and service buildings (in \$ billion), excluding operator's dwellings.
2. Implicit Price Deflator (IPD) - (Bureau of Economic Analysis 1980a, p. 40) The Implicit Price Deflator for all items in GNP.
3. Long Term Bond Rate (LTB) - (Bureau of Economic Analysis, 1980b, p. 98) The yield on U.S. Treasury Bonds with 10 years to maturity.
4. Residual Income to Production Assets (RIP) - (USDA, 1980, p. 53)
The residual return to production assets after deducting cash costs, capital depreciation, and imputed operator's labor and management from total farm receipts (USDA, 1974).
5. Total Farm Production Assets (TPA) - (Hottel and Evans, p. 63)
Market Value at February 1 of farm real estate, livestock, machinery and other farm production assets in \$ billion.

APPENDIX 2. DERIVATION OF THE ESTIMATION EQUATIONS

Equation 3.1: Rewriting (12) in terms of the backshift operator

(Sargent, p. 171) yields:

$$(1-(1-m)B)NR^*_t = m.NR_{t-1}$$

$$\text{Thus: } NR^*_t = (m.NR_{t-1})/(1-(1-m)B) \quad (\text{A.2.1})$$

Substituting into Equation 11 and multiplying through by $(1-(1-m)B)$ yields

$$FRE_t(1-(1-m)B) = m.a + b.m.NR_{t-1} + (1-(1-m)B)e_t$$

This rearranges to:

$$FRE_t = m.a + b.m.NR_{t-1} + (1-m)FRE_{t-1} + e_t - (1-m)e_{t-1} \quad (\text{A.2.2})$$

Equation 3.2: From Equation 13:

$$(1-(1-m)B)NR^*_t = mNR_{t-1} + GR^*_t \quad (\text{A.2.3})$$

and from Equation 14:

$$(1-(1-p)B)GR^*_t = pGR_{t-1} \quad (\text{A.2.4})$$

Rearranging (A.2.3) and substituting (A.2.4) into (A.2.3) gives:

$$\begin{aligned} NR^*_t &= [mNR_{t-1}/(1-(1-m)B)] + GR^*_t/(1-(1-m)B) \\ NR^*_t &= (m.NR_{t-1})/(1-(1-m)B) + pGR_{t-1}/[1-(1-m)B)(1-(1-p)B) \end{aligned} \quad (\text{A.2.5})$$

Substituting (A.2.5) into Model 11:

$$FRE = a + bNR^*_t + e_t$$

and rearranging yields:

$$(1-(1-m)B)(1-(1-p)B)FRE_t = mpa + b.m.(1-(1-p)B)NR_{t-1} + p.GR_{t-1}$$

and

$$\begin{aligned}
 [1-(1-m)B - (1-p)B + (1-m)(1-p)B^2]FRE_t &= mpa + b.m.NR_{t-1} \\
 &\quad - b(m)(1-p)NR_{t-2} \\
 &\quad + p(NR_{t-1} - NR_{t-2})
 \end{aligned}$$

and

$$\begin{aligned}
 FRE_t &= mpa + (bm+p)NR_{t-1} - (bm(1-p)+p)NR_{t-2} \\
 &\quad + (2-m-p)FRE_{t-1} + (1-m)(1-p)FRE_{t-2}
 \end{aligned} \tag{A.2.6}$$

Equation A.2.6 was estimated directly as:

$$FRE_t = d + e.NR_{t-1} + fNR_{t-2} + gFRE_{t-1} + hFRE_{t-2}$$

The five coefficients d, e, f, g, and h were then solved for estimates of the four parameters a, b, m, and p.

Equation 3.3

From Model (18):

$$FRE_t = a + b.NR_{t-1}^* + c.VAR_{t-1}$$

Since expectations of NR_{t-1}^* are formed adaptively:

$$NR_t^* = \frac{mNR_{t-1}}{(1-(1-m)B)} \tag{A.2.7}$$

Substituting A.2.8 into (14) yields:

$$FRE_t = a + \frac{bm.NR_{t-1}}{(1-(1-m)B)} + c.VAR_{t-1}$$

Cross multiplying and rearranging yields:

$$\begin{aligned}
 FRE_t &= ma + b.m.NR_{t-1} + c.VAR_{t-1} - c(1-m)VAR_{t-2} \\
 &\quad + (1-m)FRE_{t-1}
 \end{aligned} \tag{A.2.8}$$

The estimated equation:

$$FRE_t = d + eNR_{t-1} + f.VAR_{t-1} + gVAR_{t-2} + hFRE_{t-1}$$

can be solved for unrestricted estimates of the parameters.

Equation 3.4:

With different adaptive coefficients, m and n, Model (17) becomes

$$FRE_t = a + \frac{bmNR_{t-1}}{(1-(1-m)B)} + \frac{cnGR_{t-1}}{(1-(1-n)B)} \quad (A.2.9)$$

This transforms to:

$$\begin{aligned} (1-(1-m)B)(1-(1-n)B)FRE_t &= mna + bm(1-(1-n)B)NR_{t-1} \\ &+ c.n(1-(1-m)B)GR_{t-1} \end{aligned} \quad (A.2.10)$$

$$\begin{aligned} FRE_t &= mna + bmNR_{t-1} - (1-n)bmNR_{t-2} + c.nGR_{t-1} \\ &- c.n(1-m)GR_{t-2} + (2-m-n)FRE_{t-1} - (1-m)(1-n)FRE_{t-2} \end{aligned} \quad (A.2.11)$$

The following equation was used to obtain unrestricted estimates of the parameters:

$$FRE_t = d + eNR_{t-1} + fGR_{t-1} + gFRE_{t-1} + hFRE_{t-2} \quad (A.2.12)$$