An Examination of Farm Asset Returns

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Abstract: *A multi-factor capital asset pricing model is used to examine the return characteristics of physical assets comprising the farm asset portfolio. Physical assets analyzed are: 1) farm real estate; 2) machinery and motor vehicles; 3) crops stored on farm; and 4) livestock and poultry. Results for the years 1950-1990 indicate that unexpected inflation is more appropriate than the more commonly used realized inflation factor; and that the systematic risk component to these asset classes is, in general, low. Further, excess returns measures are significant for farmland, machinery, and crops stored on farm but not for livestock and poultry.*

Key Words and Phrases: *Capital asset pricing model (CAPM), Farm assets, Multi-factor models, Unexpected inflation.*

The capital asset pricing model (CAPM) is a market equilibrium paradigm that relates the rate of return on an asset (or a portfolios of assets) to the risk it contributes to the market portfolio. In the CAPM framework, the total risk of an asset can be further classified into systematic and unsystematic risks. Systematic risk is the variability in returns related to movements in the market portfolio and unsystematic risk is that which is related only to the specific asset being considered. Because unsystematic risks in a portfolio can be managed through diversification, only systematic risk is compensated in an equilibrium setting.

The Sharpe-Lintner-Mossin CAPM and related capital asset models have been used to analyze U.S. farm asset returns and systematic risk (Arthur, Carter and Abizadeh; Barry; Bjornson and Innes (1992a, 1992b); Dusak; Irwin, Forster and Sherrick). Farm real estate has received the most attention in these past studies partly because it represents by far the greatest share of the value of total farm assets, and partly because data for this asset class are readily available and fairly reliable. The vast majority of previous work has found that the returns to farm real estate have been in excess of that needed to compensate for the systematic risk farm real estate contributes to a well-diversified portfolio. Thus, farm assets have been found to be "out of equilibrium" in a positive sense for holders of farm assets. However, the results must be interpreted with caution given that farmland markets violate the CAPM assumptions of perfect capital markets, no liquidity costs, no transaction costs and perfect divisibility.

The methodological advances made in attempts to overcome empirical limitations of the simple Sharpe-Lintner-Mossin CAPM include the explicit recognition of the impact of inflation. Most notably, multi-systematic-risk-index CAPM models were proposed and employed to control for the differential impact of inflation on capital assets (Elton, Gruber and Rentzler; Brueggeman, Chen and Thibodeau). Even with these modifications, farmland appears to have earned returns in excess of those needed to compensate for both systematic market, and systematic inflation, risks. However, aggregate returns to all farm assets remain the most common data upon which these tests are conducted. In this past research, total returns were used to impute returns to farm real estate. Risk and return characteristics of other farm assets were largely ignored. Thus, although previous studies provide some guidance about returns to farmland, the performance of other asset groups remains relatively unexplored.

The main objective of this study is to examine the systematic risk and return characteristics of physical farm assets using capital asset pricing models. The approach complements previous research efforts by examining returns across the physical asset classes of: 1) farm real estate; 2) machinery and motor vehicles for farm use; 3) crops stored on farms; and 4) livestock and poultry. Another objective is to introduce a method of calculating total returns to these assets that does not introduce nonfarm market variance. Finally, an improved inflation index is employed to give additional insights into the inflation sensitivity of these assets.

The remainder of the paper is organized as follows. First, the models employed are reviewed and defined. The data are then briefly discussed (with more complete discussions provided in the appendix). Following the discussion of the methods and data are the results. Summary remarks and limitations of the study are then offered.

Related Asset Pricing Models and Applications to Agriculture

In addition to the CAPM, other asset pricing models have been employed to examine the performance of agricultural asset markets. The most prominent alternative to the CAPM is the Arbitrage Pricing Theory (APT) and its variants. Under the APT, cross-sectional asset returns are hypothesized to respond to common nondiversifiable risk "factors" with sensitivities that vary across assets. However, the greatest shortcoming of the APT is the lack of economic meaning that may be attributed to the "factors." The "factors" are simply mathematical constructs with desired properties rather than identifiable variables. However, an extension to the APT, wherein the factors are linked to explicit economic variables, confirms the importance of unexpected inflation in pricing farm real estate.

For example, Bjornson and Innes (1992a) estimate the return characteristics for the U.S. aggregate farm asset portfolio and for Illinois farm real estate using a CAPM formulation. They find that Illinois farm real estate had higher returns than non-farm assets with similar risk, but that the portfolio of U.S. farm assets had lower returns than non-farm assets with similar risk. The implication is that the other assets of the U.S. farm portfolio have substandard returns. Then, using an APT model and "rotated factors" that correspond to variables with economic interpretations, they show that inflation risk and the market risk exert the greatest influence on farmland returns. However, Bjornson and Innes made no attempt to systematically analyze the return characteristics of non-land assets in the farm asset portfolio. Further, many past studies that found farm real estate to have return premiums used a measure of farmland return that possibly overstated returns to farm real estate by understating charges for non-land equity capital or attributing all farm asset returns to farmland alone.

Bjornson and Innes (1992b) further explore farm asset returns using explicit macroeconomic risk factors. Again focusing primarily on farmland, they did not find that farm assets have earned excess returns after compensating for risk, yet conclude that farmland, which comprises approximately 75 percent of farm asset values, has earned excess returns. Others utilizing APT or explicit factor APT approaches have also encountered mixed results (Arthur, Carter and Abizadeh). As noted in Brock, a major problem in employing APT approaches is that the risk-return "benchmark" must include the asset being priced to be valid, yet, if the asset being investigated is included in the construction of the "benchmark," there are not enough statistical degrees of freedom to evaluate the asset's performance. Prescott further describes why this feature presents a particularly severe constraint in the case of specialized assets. Hence, although the APT presents an appealing theoretic alternative, problems in estimating a valid pricing measure limit its empirical applicability.[1] Instead, we opt for the more common CAPM which, even if not accepted as an equilibrium pricing model, remains a valid regression representation.

Model Formulation

The multi-index capital asset pricing model specifications employed in this study are termed the Capital Asset Pricing Model under Uncertain Inflation (CAPMUI) and the Capital Asset Pricing Model with Unexpected Inflation (CAPMUEI). The CAPMUI was used by Brueggeman, Chen and Thibodeau to examine real estate investments and by Irwin, Foster and

Sherrick to analyze farm real estate returns. Each group found that the CAPMUI was a superior specification relative to the more traditional CAPM. In this study, the CAPMUEI model specification further improves upon the CAPMUI by omitting unnecessary information about fully anticipated inflation from the model. These models are based on the simple Sharpe-Lintner-Mossin CAPM.

The familiar Sharpe-Lintner-Mossin CAPM is often stated as:

$$E(R_i) = R_f + \beta_i[E(R_m) - R_f] \tag{1}$$

where $E(R_i)$ is the expected return to asset i, R_f is the return to the riskless asset or the risk-free interest rate, $E(R_m)$ is the expected return to the market portfolio, β_i (beta) is the response to systematic market risk or $\sigma^2_{i,m}/\sigma^2_m$, where σ^2_m is the variance of the market portfolio and $\sigma^2_{i,m}$ is the covariance between the market portfolio returns and asset i.

The expected return to asset i is linearly related to the expected returns of the market by its beta. However, only *ex post* returns are observable. An *ex post* CAPM relationship may be estimated if return distributions are stationary. This relationship, often called the Jensen CAPM, may be expressed as:

$$R_i - R_f = \alpha_i + \beta_i(R_m - R_f) + \epsilon_i \tag{2}$$

where R_i is the observed return to asset i, R_f is the observed return to the riskless asset (in most empirical studies defined as the return on a U.S. Treasury instrument), β_i is asset i's relative risk measure, and ϵ_i is the error term. The term α_i is also known as Jensen's index and tests of its difference from zero are often used as evidence of returns that are more or less than required in equilibrium after adjusting for risk. For example, a positive α implies returns were higher than necessary to compensate for the systematic risk reflected in that asset's returns over time.

The Sharpe-Lintner-Mossin CAPM is not without its criticisms. The most recognizable criticism of the traditional empirical CAPM is the Roll critique. One implication of the Roll critique is that tests of significance in an empirical CAPM study are joint tests of the efficiency of the market portfolio proxy and of the β coefficient. Because results depend upon the *ex ante* efficiency of the market proxy, standard t-tests of significance may be misleading. Further, agricultural asset markets also typically violate the assumptions of perfect capital markets and are instead characterized by indivisibilities, high transactions costs, low liquidity, specialized applications and other market frictions that may make the application of a capitalization model inappropriate. Notwithstanding these arguments, past studies give evidence that there is explanatory power in the models employed. And the model remains a valid regression model even if the interpretations as an equilibrium asset pricing model are violated.

Another shortcoming of the traditional CAPM is its misspecification under inflation. Under unexpected inflation, the CAPM treats two assets having the same covariance with market returns equally (requiring the same rate of return in equilibrium) even if these assets provide differing levels of return to unexpected inflation. In the case of capital assets, inflation risk seems particularly important as a potential influence to consider in addition to the market risk.

Much theoretical work was done in the 1970s and 1980s that resulted in several alternative CAPM-like specifications (Chen and Boness; Elton, Gruber and Rentzler; Friend, Landskroner and Losq; Long). One CAPM model that accounts for the effects of inflation is the Capital Asset Pricing Model under Uncertain Inflation (CAPMUI). Brueggeman, Chen and Thibodeau argued that the following generalized form of the CAPMUI is a valid equilibrium model:

$$E(R_i) = R_f + \beta_{1i}[E(R_m) - R_f] + \beta_{2i}[E(R_\pi) - R_f] \tag{3}$$

where $E(R_i)$ is the expected return on asset i, R_f is the return to the risk-free asset, $E(R_m)$ is the expected return to the market, $E(R_\pi)$ is the uncertain inflation rate, β_{1i} is the systematic market risk of asset i and β_{2i} is the systematic inflation risk of asset i.

Empirical Capital Asset Pricing Models with Inflation Indices

The *ex post* CAPMUI model may be expressed as:

$$(R_i - R_f)_t = \alpha_i + \beta_{1i}(R_m - R_f)_t + \beta_{2i}(R_\pi - R_f)_t + (\epsilon_i)_t \tag{4}$$

where $(R_i - R_f)_t$ is the excess return to asset i in time period t, $(R_m - R_f)_t$ is the excess return to the market in time period t, $(R_\pi - R_f)_t$ is the excess rate of inflation in time period t, and $(\epsilon_i)_t$ is the error term that is assumed to be normally distributed with an expected value of zero. If the data generating process is stationary, the model can also be used to estimate expected or *ex ante* returns. The coefficients β_{1i} and β_{2i} are asset i's response to market risk and inflation risk, respectively. The regression intercept, α_i, is an index of asset performance under uncertain inflation. Analogous to tests under the traditional CAPM, a significantly positive (negative) α_i indicates returns greater (less) than needed to compensate investors for systematic market risk and inflation risk.

For this analysis, a further modification to the empirical model is proposed. An issue in empirical works relates to the definition of the inflation indices and the portion of inflation that is not correctly anticipated or expected by investors. Fama as well as Fama and Schwert defend the use of the previous period's T-bill rate as the expected inflation rate for the current period. Then, deviations about that level are taken as "unexpected" measures of the inflation. The unexpected inflation index in this paper follows that convention (also termed the unanticipated inflation index in Brueggeman, Chen and Thibodeau) and is put into excess form to allow the interpretation of the intercept as the Jensen index. Developments in rational expectations theory and multi-index model building indicate that only the unexpected component of an index is important because investors have already incorporated the effects of anticipated inflation into the price of the assets (Haugen).

The model used in the empirical study is similar to the Jensen excess returns model. The two index model with unexpected inflation can be written similarly to equation (4) except that the anticipated portion of inflation is excluded from the inflation index. The resulting model is:

$$E[R_i] - E[R_f] = a_i + b_{1i}(R_m - R_f) + b_{2i}(E[\pi^*] - E[R_f]) + e_i \qquad (5)$$

where R_i is the nominal return to asset i; R_f is the return to the risk free asset; a_i is the intercept with $E[a_i] = 0$; b_{1i} is the asset's market beta; R_m is the nominal return to the market index; b_{2i} is the asset's unexpected inflation factor beta; π^* is now the unexpected inflation factor return index, and e_i is the error term.

Market Index

The Ibbotson, Siegel and Love's annual U.S. market index was used in an attempt to mitigate concerns related to the use of an exchange specific, or all equity, market index. In particular, use of the S&P 500 has been shown to depend critically on the treatment of implied dividends and the use of the New York Stock Exchange indices depends on the weighting scheme used (see Green for a more complete discussion on this point).

The Ibbotson, Siegel and Love's annual U.S. market index is meant to provide an approximation of the composition of the total U.S. investment portfolio. However, this market portfolio is not all-inclusive since some investments, such as the value of many small businesses, personal holdings, and human capital, are omitted from the estimates. However the index components do account for investments that are most marketable, identifiable and available to most investors. Further, it is a much broader index than used in most previous studies.

The Ibbotson, Siegel and Love's series was published for the years 1947-84, but an updated index was not available at the time of this study. Hence, an instrumental variable was constructed using components of the market index. The regression used as the basis for constructing the instrument is reported in Table 1. The fit between the observed and predicted variables was very good as evidenced by the R^2 between predicted and observed values of 0.9 and the overall adjusted R^2 of 0.86. To further examine the sensitivity of the model to the approach used, several sensitivity tests were performed. These are described later, but, in general, the instrumental variable approach gave qualitatively similar results to all models using only published data.

Percentage changes in the consumer price index were used as realized total inflation rates. Following traditional CAPMUI formulations, uncertain inflation was defined as the annual percentage change in the consumer price index in period *t* less the T-bill rate of return in period *t*. Unexpected inflation was defined as in Fama, and Fama and Schwert, and the unanticipated inflation index in Brueggeman, Chen and Thibodeau. Excess formulations were then used to allow the interpretation of the intercept as Jensen's index of risk-adjusted performance.

Farm Asset Returns

The data on farm assets returns are all national level aggregate measures from the *Economic Indicators of the Farm Sector: National Financial Summary 1990*. The methods of calculating the rates of return, and the procedures for allocating to the various asset classes, are discussed in detail in the appendix. It is important to note, however, that the results of the study depend on the adequacy of the allocation procedures in addition to the model specification.

Summary statistics of the data series are given in Table 2. For the period 1950-1990, the mean returns to farm real estate, motor vehicles and machinery, and the livestock and poultry asset groups, were higher than the market index. However, the standard deviations for farm real estate and the livestock and poultry asset group are larger than the standard deviation of the market. The farm motor vehicles and machinery asset group performed well relative to the market. This is an unusual but plausible finding since these farm assets are traded in "thin" markets and their performance should be judged in a more complete portfolio context.

Table 1.
Regression Results for Market Index Instrumental Variable[a]

Assets	Estimated Coefficient	*T*-Ratio
Constant	2.29	2.03
S & P 500	0.14	3.95
Small Stocks	0.07	3.49
Long-Term Corporate Bonds	0.14	1.14
Long-Term Government Bonds	0.02	0.17
Government Bonds	-0.07	-0.37
Treasury Bills	0.07	0.31
Farm Real Estate	0.01	0.11
Consumer Price Index	0.46	2.63
Adjusted R^2	0.86	
R^2 Between Observed and Predicted	0.90	
Durbin-Watson Statistic	1.69	

[a]Regressions were corrected for first order autocorrelation using the Cochrane-Orcutt procedure.

The other physical farm asset group, crops stored on the farm, had lower mean returns than the market. In contrast, this physical farm asset group had a larger standard deviation and, thus, a larger coefficient of variation relative to the market. The standard deviation for storing crops on the farm is quite large. Also of interest, the mean return to the crops group is similar to that of inflation. The last item of mention is that, consistent with expectations, the mean return to the unexpected portion of inflation is not significantly different from zero.

Of equal importance to summary statistics are the correlation coefficients of the asset return series. It is shown in Table 3 that the physical farm asset groups (farm real estate; motor vehicles and machinery; and livestock and poultry) have positively correlated returns with the market index. The returns from crops stored on the farm are negatively related to the market index return. With respect to the inflation indices, all farm physical asset groups are positively correlated to the consumer price index and the unexpected inflation index.

Table 2.
Summary Statistics for Nominal Rates of Return on Farm Physical Assets, Treasury Bills, U.S. Market Portfolio and Inflation Rates, 1950-90

Assets	Mean Return	Standard Deviation	Coefficient of Variation
Farm Real Estate	8.66	7.37	0.85
Motor Vehicles and Machinery	8.58	3.88	0.45
Livestock and Poultry	13.03	32.15	2.47
Crops	4.39	7.50	1.71
90 Day Treasury Bills	5.31	3.21	0.60
Consumer Price Index	4.30	3.30	0.78
Unexpected Inflation Index	-0.85	2.94	-3.47
Market Portfolio Index	8.20	4.54	0.55

Sources: Computed from USDA, and Ibbotson, Siegel and Love.

Although not surprising, the farm real estate returns are positively correlated to the other physical farm asset group returns. Livestock and poultry returns are the least related to farm real estate returns. In fact, the livestock and poultry class appears to be the least related to the returns of the all other farm asset class returns. The low correlation between livestock and poultry and other asset groups is consistent with the time-honored wisdom that farmers can diversify with livestock. Finally, the unexpected inflation index is negatively correlated to the U.S. T-bill return index and the market index as expected.

Asset Pricing Model Results

The return characteristics of 1) farm real estate; 2) motor vehicles and machinery; 3) livestock and poultry; and 4) crops stored on the farm, are listed in Tables 4-7, respectively. The CAPMUI specification results indicate that some asset class returns do show premiums in excess of their systematic risk in contrast to the aggregate results of Bjornson and Innes.

Table 4 shows that for farm real estate, the CAPMUEI specification intercept is 10.82. The market beta is not significantly different from zero in agreement with nearly all previous studies. The unexpected inflation beta of 1.28 indicates that farm real estate returns react more than proportionately with unexpected inflation in agreement with past evidence. And the fit of the model is improved slightly relative to that under the more common

Table 3.
Correlations of Nominal Returns, Various Asset Classes, 1950-1990

Category	T-Bills	CPI	Unexpected Inflation	Real Estate	Machinery & Motor Vehicles	Livestock & Poultry	Crops on Farm	Market Index
T-Bills	1.00							
CPI	0.73	1.00						
Unexpected Inflation	-0.16	0.46	1.00					
Real Estate	-0.13	0.35	0.70	1.00				
Machinery & Motor Vehicles	0.29	0.67	0.53	0.68	1.00			
Livestock & Poultry	-0.04	0.04	0.08	0.36	0.08	1.00		
Crops on Farm	0.01	0.10	0.23	0.43	0.16	0.06	1.00	
Market Index	0.18	0.24	-0.15	0.02	0.17	0.07	-0.23	1.00

Table 4.
Farm Real Estate Capital Asset Pricing Results, 1950-1990[a]

Explanatory Variable	CAPM-Unexpected Inflation	CAPM-Uncertain Inflation
	Capital Asset Pricing Model Type[b]	
Intercept	10.82***	4.11*
	(4.73)	(1.88)
Market Beta	0.23	0.18
	(1.60)	(1.10)
Unexpected Inflation Beta	1.28***	N/A
	(4.78)	
Uncertain Inflation Beta	N/A	0.98**
		(2.03)
Adjusted R^2	0.68	0.55
Durbin-Watson Statistic	1.99	1.85

[a]Regressions were corrected for first order autocorrelation using the Cochrane-Orcutt procedure.
[b]*T*-ratios are in parentheses. Asterisk(s) indicate the coefficient is statistically different from zero at the 0.10 (*), 0.05 (**) or 0.01 (***) level of significance.

CAPMUI specification. Interpreting the intercept as Jensen's α indicates that under the CAPMUEI specification, there were substantial rewards to owning farm real estate.

One would expect that in a perfect market, this premium would be driven to its expected value of zero. In a perfect market setting, investors would be able to bid away this "arbitrage-like" premium. However, in the farm real estate market, these premiums are not easily bid away because farm real estate is bought and sold in an non-liquid market with high transaction costs.

As reported in Table 5, the market beta estimate of the CAPMUEI specification is significantly different from zero at the 10 percent level. The farm motor vehicles and machinery asset group has a significant and positive unexpected inflation beta of 0.58. This coefficient is lower than that of farm real estate and in accordance with intuition. The CAPMUEI estimate of the intercept is 6.58 percent. These results are similar to those for farm real estate. Again, this asset group consists of specialized assets that probably preclude the extraction of the premium by outside investors.

The market beta for motor vehicles and machinery used on the farm estimated from the CAPMUI specification is not significantly different from

Table 5.
Motor Vehicles and Machinery Capital Asset Pricing Results, 1950-1990[a]

Explanatory Variable	Capital Asset Pricing Model Type[b] CAPM-Unexpected Inflation	CAPM-Uncertain Inflation
Intercept	6.58***	3.91*
	(5.28)	(4.10)
Market Beta	0.14*	0.09
	(1.98)	(1.16)
Unexpected Inflation Beta	0.58***	N/A
	(4.06)	
Uncertain Inflation Beta	N/A	0.76**
		(3.39)
Adjusted R^2	0.65	0.62
Durbin-Watson Statistic	1.88	1.95

[a]Regressions were corrected for first order autocorrelation using the Cochrane-Orcutt procedure.
[b]*T*-ratios are in parentheses. Asterisk(s) indicate the coefficient is statistically different from zero at the 0.10 (*), 0.05 (**) or 0.01 (***) level of significance.

zero. The inflation beta is significant and positive. Furthermore, this asset group has a significant Jensen's index of 3.91 percent.

The CAPMUEI and CAPMUI estimates of the market beta for the livestock and poultry group are very high compared to the other asset classes, yet the estimates are not significantly different from zero. Also, there is apparently no return premium above that for systematic risk. Furthermore, this asset group displays no reaction to inflation under either specification. These results for the livestock and poultry group are expected because this group of assets does not have a substantial support mechanism through which premiums can be maintained.

The return characteristic of crops stored on farms are in Table 7. The CAPMUEI estimate of the intercept (4.73) for the crops group is significant. The market beta estimate is not significantly different from zero and the unexpected inflation beta is positive (0.82) and significant.

The estimates under the CAPMUI specification differ indicating that crops have little systematic risk, are not significantly positively related to inflation, and offer no premiums above those for systematic risk. These estimates are in accordance with those for the farm real estate group and the

Table 6.
Livestock and Poultry Capital Asset Pricing Results, 1950-1990

	Capital Asset Pricing Model Type[a]	
Explanatory Variable	CAPM-Unexpected Inflation	CAPM-Uncertain Inflation
Intercept	12.76 (1.18)	7.61 (1.04)
Market Beta	0.79 (0.73)	0.78 (0.71)
Unexpected Inflation Beta	1.07 (0.82)	N/A
Uncertain Inflation Beta	N/A	1.42 (0.58)
Adjusted R^2	0.01	0.00
Durbin-Watson Statistic	1.89	1.87

[b]*T*-ratios are in parentheses.

motor vehicle and machinery group. Further, this result seems likely given the number of on-farm storage units erected during this period.

The results from the CAPMUEI and CAPMUI specifications are similar. However, the CAPMUEI specification tends to fit the data better. The CAPMUEI specification was expected to be more efficient because the CAPMUI contains anticipated inflation in the inflation factor index and investors in the market should have properly accounted for these anticipated movements.

To test the sensitivity of the results to the model specifications employed, several other tests were conducted. First, the S&P 500 index and the reported portion of the Ibbotson index were used in place of the instrumental variable as proxies for the market index. The results were qualitatively quite similar except that the R^2 measures were uniformly lower. Data subsamples up to 1984 and then up to 1988 were also examined under similar models. Again, there were no substantial differences in the results beyond slightly changed levels of significance. Finally, the original Ibbotson market index was augmented with predicted values of the index in lieu of the instrumental variable. The results were again nearly identical with no changes in signs or significance across all asset classes.[2]

Table 7.
Crops Stored on Farms Capital Asset Pricing Results, 1950-1990

Explanatory Variable	Capital Asset Pricing Model Type[a] CAPM-Unexpected Inflation	CAPM-Uncertain Inflation
Intercept	4.73**	0.39
	(2.18)	(0.24)
Market Beta	-0.26	-0.17
	(-1.00)	(-0.62)
Unexpected Inflation Beta	0.82***	N/A
	(3.18)	
Uncertain Inflation Beta	N/A	0.91
		(1.64)
Adjusted R^2	0.17	0.02
Durbin-Watson Statistic	2.07	1.79

[a]*T*-ratios are in parentheses. Asterisk(s) indicate the coefficient is statistically different from zero at the 0.10 (*), 0.05 (**) or 0.01 (***) level of significance.

Summary and Limitations

This study used multifactor CAPM models to examine the return characteristics across several farm asset classes. In contrast to the Bjornson and Innes study, farm asset classes had excess return premiums above their returns to systematic risk. Thus, farm assets were not dominated by nonfarm investment returns. Further, in contrast to past studies, a CAPMUEI model that explicitly included the effect of unexpected inflation was used to study the return characteristic of farm asset classes. In addition, the returns measure employed did not likely inflate the returns to farm real estate as was possible in some previous studies.

Farm physical assets have characteristics that may cause their returns to deviate from the equilibrium levels, those theoretically expected in a perfect market setting with infinitely divisible assets, zero transactions costs, and no other frictions. Farm real estate is instead characterized as a highly non-liquid asset that has high transaction costs for buying and selling and is subject to many other influences and market frictions. The findings of positive excess returns (Jensen's α) are consistent with an non-liquid asset with high acquisition and disposition costs. Arbitrage-like profits for holding this asset may appear positive because the transaction costs offset the premiums to the point at which net arbitrage profits are zero. Thus, those who held farm real estate during this period reaped returns in excess of those required to compensate for risk, yet transactions costs prevent others from directly capturing the premium.

Premiums for holding physical farm assets are apparent for all agricultural assets except livestock and poultry. The intercept, reflecting any excess returns relative to systematic risk, is not significantly different from zero for the livestock and poultry physical assets. These results may reflect the fact that livestock and poultry do not have substantial government support programs. On the other hand, the estimated beta for livestock and poultry is insignificantly different from one, the beta of the market portfolio. Investments in livestock and poultry do offer competitive returns compensating for their systematic risks despite the lack of government support programs.

The implications from this analysis of farm rates of return to assets are that the assets used in the farm sector have earned more than adequate returns during this time period. Further, both assets that were directly supported by governmental transfer programs and assets that were not supported were found to offer competitive returns for their risk levels.

Although this study is constrained by data limitations, measurement error and the validity of the capital asset pricing paradigm, the results are consistent with implications of financial and economic theory. Thus, although the results must be interpreted with care, they do offer some additional insights into the behavior of asset classes employed in agricultural production, subject to the performances of the markets in which they are traded.

This study suggests that future work that quantifies the transactions costs for acquiring and disposing of agricultural assets would be valuable. Estimates of these costs could then be compared to excess return measures to provide evidence of barriers to capital flows in agricultural asset markets. Further, other data sources should be considered, especially survey-based measures of returns to specific asset classes and segments not explicitly considered in this study.

Notes

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1. A simple example demonstrating the pitfalls in this approach is given below. First, consider a three-state, three-asset economy as the simplest "pure" APT world. In this example, an exact fit APT is given that exactly exhausts the relevant factors. Asset returns are given across rows and states corresponding to factors are represented as columns in the first matrix, $\boldsymbol{Y}$. The $\boldsymbol{P}$ matrix gives the state prices with the resulting prices in $\boldsymbol{V}$.

$$\underset{\boldsymbol{Y}'}{\begin{bmatrix} 2 & 1 & 0 \\ 2 & 2 & 0 \\ 1 & 1 & 2 \end{bmatrix}} \times \underset{\boldsymbol{P}}{\begin{bmatrix} 1/4 \\ 1/4 \\ 1/4 \end{bmatrix}} \underset{=}{=} \underset{\boldsymbol{V}}{\begin{bmatrix} 3/4 \\ 1 \\ 1 \end{bmatrix}}$$

Suppose "empirical security returns plane" were first constructed from assets 1 and 2 alone. The solution to $\boldsymbol{Y}_2'\boldsymbol{P}_2 = \boldsymbol{V}_2$ would be found to be valid in pricing assets 1 and 2, and hence judged as a "valid" for assets in the economy as below:

$$\underset{\boldsymbol{Y}_2'}{\begin{bmatrix} 2 & 1 \\ 2 & 2 \end{bmatrix}} \times \underset{\boldsymbol{P}_2}{\begin{bmatrix} 1/4 \\ 1/4 \end{bmatrix}} \underset{=}{=} \underset{\boldsymbol{V}_2}{\begin{bmatrix} 3/4 \\ 1 \end{bmatrix}}$$

However, applied to asset 3, the empirical security market plane would imply a price of 1/2 through $\boldsymbol{Y}_3'\boldsymbol{P}_3 = \boldsymbol{V}_3$ even though the observed price is 1. Asset 3 is "specialized" in that it contains returns in states that are not priced by the assets used to construct the empirical pricing function. Hence, applying an APT approach to this economy will either conclude that asset 3 is overpriced relative to the empirical security plane, or that the security market plane permits arbitrage. Prescott also elaborates to demonstrate how an estimated APT from a subset of all assets could also result in incorrectly identifying the number of important factors.

2. The results of these sensitivity tests are available from the authors upon request.

References

Arthur, Louise M., Colin A. Carter, and Fay Abizadeh. "Arbitrage Pricing, Capital Asset Pricing, and Agricultural Assets." *Amer. J. Agr. Econ.* 70(1988): 359-65.

Barry, P.J. "Capital Asset Pricing and Farm Real Estate." *Amer. J. Agr. Econ.* 62(1980): 549-53.

Barry, P.J., and L.J. Robinson. "Economic Versus Accounting Rates of Return on Farm Land." *Land Economics* 62(1986):388-401.

Bjornson, B., and R. Innes. "Another Look at Returns to Agricultural and Nonagricultural Assets." *Amer. J. Agr. Econ.* 74(1992a):109-19.

_______. "Risk and Return in Agriculture: Evidence from an Explicit Factor Arbitrage Pricing Model." *J. Agr. Res. Econ.* 17(1992b):232-252.

Brock, W.A. "Asset Prices in a Production Economy." *The Economics of Information and Uncertainty,* ed. J.J. McCall, pp. 1-41. Chicago, IL: University of Chicago Press, 1982.

Brueggeman, W.B., A.H. Chen, and T.G. Thibodeau. "Real Estate Investment Funds: Performance and Portfolio Considerations." *Amer. Real Est. and Urban Econ. J.* 12(1984):333-54.

Chen, A.H., and A.J. Boness. "Effects of Uncertain Inflation on the Investment and Financing Decisions of a Firm." *J. Fin.* 30(1975):469-483.

Dusak, K. "Futures Trading and Investor Returns: An Investigation of Commodity Market Risk Premiums." *J. Polit. Econ.* 81(1973):1387-1406.

Elton, E., M. Gruber and J. Rentzler. "The Arbitrage Pricing Model and Returns on Assets Under Uncertain Inflation." *J. Fin.* 38(1983):525-537.

Fama, E.F. "Short Term Interest Rates as Predictors of Inflation." *Amer. Econ. Rev.* 65(1975):269-82.

Fama, E.F., and W.G. Schwert. "Asset Returns and Inflation." *J. Fin. Econ.* 4(1977):115-46.

Friend, I., Y. Landskroner, and E. Losq. "The Demand for Risky Assets Under Uncertain Inflation." *J. Fin.* 31(1976):1278-1297.

Green, R.C. "Benchmark Portfolio Inefficiency and Deviations from the Security Market Line." *J. Fin.* 41(1986):295-312.

Haugen, Robert A. *Modern Investment Theory.* Englewood Cliffs, NJ: Prentice-Hall, 1986.

Ibbotson, R.G., and C.L. Fall. "The United States Market Wealth Portfolio." *J. Portfolio Mngmnt.* 5(1979):82-92.

Ibbotson, R.G., L.B. Siegel, and K.S. Love. "World Wealth: U.S. and Foreign Market Values and Returns." *J. Portfolio Mngmnt.* 11(1985):1-21.

Irwin, S.H., D.L. Forster, and B.J. Sherrick. "Returns to Farm Real Estate Revisited." *Amer. J. Agr. Econ.* 70(1988):580-87.

Jensen, M. "The Performance of Mutual Funds in the Period 1945-64." *J. Fin.* 23(1968):443-45.

Lintner, J. "The Valuation of Risk Assets and the Selection of Risky Investments in Stock Portfolios and Capital Budgets." *Rev. Econ. and Stat.* 47(1965):13-37.

Mossin, J. "Equilibrium in a Capital Asset Market." *Econometrica* 34(1966):768-83.

Prescott, E.C. "Discussion: Asset Prices in a Production Economy by W.A. Brock." *The Economics of Information and Uncertainty,* ed. J.J. McCall, pp. 43-46. Chicago, IL: University of Chicago Press, 1982.

Roll, R. "A Critique of Capital Assets Pricing Theory's Tests." *J. Fin. Econ.* 4(1977):129-76.

Sharpe, W.F. "Capital Asset Prices: A Theory of Market Equilibrium Under Conditions of Risk." *J. Fin.* 19(1964):425-42.

U.S. Department of Agriculture. *Economic Indicators of the Farm Sector: National Financial Summary.* Washington, DC: Selected issues.

_______. *The Balance Sheet of the Farming Sector.* Sup. No. 1, AIB-389. Washington, DC: Apr. 1976.

Appendix

Return Definitions and Allocation Procedures

Total returns are defined as the sum of current residual returns to farm physical assets and capital gains from ownership of physical assets. Capital gains information is published by the U.S. Department of Agriculture (USDA) for: 1) farm real estate; 2) machinery and motor vehicles for farm use; 3) crops stored on farms; and 4) livestock and poultry. Hence, the same asset groups are used in this study.

Current Return Allocation to Farm Physical Assets. The procedure for allocating current returns among farm physical assets is similar to the method employed by Barry to allocate returns to farm real estate. First, the current return from farm production and real estate ownership is estimated as the total net income of farm operators from farming plus cash wages and perquisites of hired labor; interest on real estate and non-real-estate debt; net rent to landlords; and the imputed portion of rental value of farm dwellings.

These data are all national level aggregate measures from the *Economic Indicators of the Farm Sector: National Financial Summary 1990.*

Next, the current return from production and real estate ownership is reduced by imputed returns to total farm labor, management and non-physical assets to yield a residual return to farm physical assets. The imputed returns to total farm labor and management are published, but the imputed returns to non-physical assets are not.

The annual return to non-physical assets is estimated as the sum of interest paid on non-physical asset debt and the opportunity costs on equity in non-physical assets. The annual interest paid on non-physical assets is defined as the interest paid on non-real-estate debt multiplied by the proportion of non-physical assets to non-real-estate assets. The annual opportunity cost of equity in non-physical assets is defined as the equity in non-physical assets multiplied by the annualized return to short-term U.S. Treasury obligations. For the time period studied, the non-physical asset group averaged 7 percent of total assets. Thus, potential errors in allocating returns should have little effect on the results of this study.

The current returns to physical farm assets are then distributed to the asset groups based on their proportion of asset value to total physical asset value for each time period for each asset category. To test the sensitivity of the results to this assumption, several other approaches were undertaken. For example, current returns were regressed against asset class values and the coefficients used to decompose total returns using the relationship that total returns equal the sum of the weighted returns across all assets. Further average asset values were used to allocate total returns through time to the asset classes. None of these alternative procedures led to improved models.

The procedure used also allocates the systematic risk of current income to the asset classes. As pointed out by a reviewer, this relationship is most appropriate if each of the individual asset classes is subject to similar capitalization arguments. In other words, if current values of each asset class are equal to discounted expected values of future income streams, then allocating current income based on relative asset values is appropriate. To the extent that assets do not reflect this fundamental relationship, the procedure risks mismatching income flows with asset classes.

Capital Gains to Farm Physical Assets. The capital gain from farm real estate ownership in period t is calculated as farm real estate value in period t less the value of farm real estate in period t-1 less the difference between capital investments in real estate and depreciation during period t.

For the years 1960-1990, the published capital gains series for 1) machinery and motor vehicles used on the farm; 2) livestock and poultry; and 3) crops stored on farms were taken from the *Economic Indicators of* *the Farm Sector: National Financial Summary*. However, USDA published only the component of the series, and not the actual series over the decade of the 1950s. Hence, the capital gains series for these groups during 1950-1959 were computed using the same procedure used by USDA to calculate the series they did publish (USDA, 1976). The calculated capital gains on farm machinery and motor vehicles used in farm production are defined as the difference in the value of machinery and motor vehicles (excluding operator households) for the year less net investment. Net investment is defined as capital expenditures for these items less depreciation and accidental damage. Each of these accounts are found in the *Economic Indicators of the Farm Sector: National Financial Summary* except for the accidental damage. Accidental damage is grouped for both service structures, machinery and motor vehicles in that publication. Hence, the portion attributable to machinery and motor vehicles was calculated by dividing the inventory value for machinery and motor vehicles by the total value of service structures, machinery and motor vehicles and then multiplying this proportion by the annual charge for accidental damages.

The calculated capital gains on livestock and poultry are defined as the difference in balance sheet values at the end of the year less the difference in inventory value change. The difference in inventory value is defined as the change in end-of-year livestock and poultry numbers times the average yearly price. The average yearly price is defined as the average of end-of-year per head price for the previous year (the beginning of the year price) and the end-of-year price for the current year. Finally, the capital gains on crops are defined as the difference in end-of-year balance sheet values for crops less the change in CCC crop loans and less the value of the change in inventory.

The implications of the return allocation procedure are as follows. First, because the current returns are allocated by the capitalized value of the asset, the current rate of return is allocated proportionally across farm asset groups. Although this allocation method is imperfect, past allocation methods assumed that returns to farm assets other than farm real estate earned the 90-day T-bill rate. Thus, although this allocation method is somewhat arbitrary, it does not introduce variation due to nonfarm assets into the allocation method. Further, differences in the systematic risk of each farm asset group are determined by expected growth in earnings from asset groups, the capital gain. Thus, changes in expected earnings drive the systematic risk of farm assets with this allocation method.

A second implication is that this analysis relies heavily on the valuation of aggregate farm assets. Some of the aggregate measures are calculated and are not survey based. Thus, substantial measurement error is plausible.

On the other hand, it is not readily apparent USDA would systematically mismeasure the assets and their associated gains as reported in the *National Financial Summary*. Thus, results from this analysis should be interpreted with care and the results interpreted with the recognition that they rely on the joint hypotheses of data adequacy and model appropriateness.