Farmland price bubbles: wavelet-based evidence

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by
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Abstract

Land is the most important agricultural asset. Income risk due to farmland price volatility creates economic hardship for rural communities. Although inflation explains much of the farmland valuation problem, it remains to some extent a puzzle. We use wavelet-based statistical methods supported by econometrics to test a simple asset pricing model of land values in which a speculative price bubble is found in the real option value to land development. Theory suggests land as an asset is a good candidate for this hypothesis. The results show that a short-run speculative bubble appears to have been active in some years.

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1. Motivation

Land represents about 75-85% of the value of agricultural assets. The price of farmland is volatile, both in nominal and real terms. Research in agricultural finance is generally concerned with understanding the sources of risk in the rural economic sector and agribusiness area. Volatility in the value of rural land creates income risk that is likely systematic and which therefore is related to decisions made about risk management regarding other sources of risk such as price risk or yield risk. Large swings in land value lead to increased credit and default risk and more broadly, hardship for rural communities with permanent negative effects.

A large research literature has studied the question of farmland valuation and whether this may be determined by fundamental explanations such as a measure of rent or net farm income returns. This classic literature has adopted an empirical asset pricing framework to test different hypotheses on "fundamentals" (Phipps, Alston, Miranowski and Just, Mishra and Moss, Myers and Hanson). For example, there is no strong evidence that farmland returns or rent explain or determine farmland values (Featherstone and Baker). Although inflation explains a large share of land price variation (Moss), because purchasing land is seen as a hedge against foreseen increases in the general level of prices in the economy (and the supply of land is essentially fixed), the farmland valuation puzzle remains (Moss and Katchova).

In recent years the literature has focused on relaxing assumption of perfect markets, namely by investigating the role played by nontrivial transaction costs (Chavas; Lence and Miller), institutional and social factors (Hardie et al., Tsoodle et al.), and the value of real options to land development as caused by urban pressure on the fringe (Turvey). Important policy considerations have also been examined in depth (Moss and Schmitz, ed.).

2. Asset value bubbles

We consider in this paper a rational, stochastic bubble. Irrational bubbles or fads have found some support in the behavioral finance literature. Stochastic rational bubbles are characterized, broadly speaking, by a probability of bursting or crashing at each time period. Rational explanations models have been used to explain why assets are held despite knowledge of the bubble (Tirole). Bubbles may emerge in such minimal environments as the case of two traders with common knowledge (Conlon).

Jarrow et al. provide a different treatment of bubbles using a martingale-based mathematical approach. They prove that bubbles are of three and only three types. They show that if the relevant asset markets are complete, a bubble would be trivial and of no economic interest. However, if markets are incomplete, such that Put-Call Parity (a fundamental identity relating financial options with underlying asset values), does not hold, then a nontrivial bubble may exist in the value of an option.

The market for agricultural land is imperfect due to significant transaction costs (Lence and Miller; Chavas) and other institutional factors. Research has found evidence of a real option to the value of land development (Turvey) which may be explained by urban pressure (Livanis, Moss, Breneman and Nehring). We therefore consider the hypothesis of a speculative bubble in the value of farmland, located in the real option to land development due to urban sprawl and real estate bubbles.

3. Description of the data, methods and empirical strategies

This paper adopts a time series-based approach, and uses both established econometric methods as well as wavelet-based statistical approaches. The latter are described in the next section of the paper. The data used consist of annual USDA-collected State-average agricultural land prices per acre (a different time series for each of 48 contiguous states) as well as annual State-average agricultural rents or returns, estimated from net farm income per state adjusted for the proportion of agricultural land in each state. (USDA-NASS, through Cornell's Mann Library database of agricultural statistics). A complete dataset is available for the years 1949-2005. The data are deflated by the Consumer Price Index (Bureau Labor Statistics) to adjust for inflation. To create a time series for the risk-free rate of interest in this asset pricing framework, data are obtained for both the 3-month T-bill and the commercial paper rate. Indeed, the 3-month T-bill is only a recently available financial instrument. These data are obtained from the St. Louis Federal Reserve Bank database (FRED).

Some concerns should be addressed regarding the quality of the data used in this study. First, it is well understood that the collection and estimation design of state-average land prices by the USDA may not homogeneous or consistent through the years. Therefore, the effect of statistical noise in the data may not be negligible (Lence and de Fontnouvelle). Second, the aggregation of data into annual averages masks potentially important differences at shorter time periods as well as between different counties or regions in each state (Schmitz) Third, there is no consensus on the proper definition of the Ricardian residual return to land. Mishra, Moss and Erickson evaluate different methods of estimating returns, based on whether values are imputed or not. It is not clear that there is a preferred method.

To address these issues in future work, the analysis will be extended to county-level data and transaction-level data (through Department of Revenue-mandated "green sheets") that record transactions of land sales and purchases. However, the irregular frequency of transactions may prove difficult to work with. To consider problems with the measure of land returns, sensitivity of the results to various definitions will be tested. Land rents will be defined and measured according to different motivations and the tests redone in each case to assess robustness. Important recent work looks at spatial patterns of land prices, going beyond hedonic price models and using detailed geographic information and measures of spatial autocorrelation, for example (Huang et al., Livanis et al.).

4. Wavelets: definition and illustrations

It is often desirable in various applied mathematical problems to find an approximate representation of a complicated, perhaps non-differentiable, function or stochastic process. Harmonic analysis and Fourier analysis use sine and cosine functions, but these sinusoids are ill-suited for typical economic and financial time series. In contrast to the "long, smooth waves" that characterize sines and cosines, "short, rough waves" correspond to so-called wavelet functions. Wavelets are continuous and differentiable and offer a superior method to approximate or decompose stochastic processes or time series data.

Wavelet-based analysis is Real-valued, unlike Fourier-based methods, and represents the data over time and scale, rather than frequency. This provides a more economically intuitive representation of the data or process. Indeed, scales may be defined as specific time horizons (short, intermediate, long) in the context of economics and finance. Wavelet analysis is unbiased in the presence of nonstationary data and addresses well singularities in the data such as jumps, spikes, etc.

While wavelets were discovered as early as 1910, it is only in the 1980s that important breakthroughs were made which enabled a vast number of applications in engineering and the natural sciences. The steps involved in wavelet analysis as it is used in this paper may be summarized as follows. The approach is similar to that of signal extraction problems sometimes found in macroeconomics.

(1) An appropriate wavelet function ψ is selected based on the problem being studied and is then fixed. (2) A basis of dilations and translations of this original function ψ is computed. (3) If possible, parameters are chosen to ensure a sparse basis, which has significant advantages for empirical applications. (4) Preferably, the basis should be orthogonal in the space of all square-integrable functions such that any function in L^2 space may be represented by wavelets. (5) Associated with the wavelet function ψ is a scaling function ϕ. (6) Using the translated, dilated wavelet functions and the scaling function, a wavelet representation of any function in L^2 space may be obtained.

<u>5. Results</u>

The farmland valuation puzzle is the empirical fact that US agricultural land prices (real or nominal) have been highly volatile during much of the 20th century and appear to have systematically deviated from estimated fundamental determinants such as rent or land returns. While inflation explains well a significant amount of this variation over time (Moss), another possible explanation is a rational price bubble driven by non-fundamental variables.

Using wavelet-based nonparametric methods, we find that the volatility of rural land values appears to have increased in the last ten years of data, in particular at the shortest time horizons (yearly, biyearly,…). We first estimate persistence (long memory) in both land values and land rents for all 48 contiguous states and over the available time series. We find that both variables display significant long memory and non-stationarity. We then adapt Hamilton and Whiteman's method to test whether we can reject a null hypothesis of *no bubble* in land values. We estimate long memory in the two time series after differencing once. While land rents are weakly mean-reverting (antipersistent) in difference (for all states, with minor variations), land values display across all states long memory even after differencing. Therefore, we cannot reject the null and, following Hamilton and Whiteman, we interpret the findings as evidence to support a speculative bubble in land prices.

To identify the source of persistence in the data, we test, for all 48 states and at every time scale, whether the wavelet-based variance is homogeneous. Rejecting the null implies that for a given time horizon (say, a short, one-year time horizon) and a given state, land price volatility has increased over the years. Shorter time horizons are plausibly associated with market activity of a more speculative nature, while longer time horizons are associated with long-run macroeconomic fundamentals. The tests are conducted by Monte Carlo (40,000 replications) as no asymptotic results exist yet. Asymptotically valid Monte Carlo test distributions are estimated for the 1%, 5% and 10% levels of significance, against which are compared the test values from the actual data. Our findings show that for most states, the volatility of land prices is indeed due to activity at the shortest time horizon (1-2 years), and in addition, that price volatility at the longest time horizon has not increased over the years.

Lastly, we reconsider the co-integrating, long term relationship between land values and land rents. We test for Granger-causality between the two variables and in particular are interested in whether (CPI-deflated) land values are well explained by a fundamental economic variable, land rents. We use wavelets to decompose the data and then create artificial time series, each of which corresponds to the proportion of the original data that is due only to one given time horizon. Each artificial time series is valued in the original metric (average dollar value per 1000 acres agricultural land). A simple Autoregressive model (AR(p)) is estimated by maximum likelihood with lags determined on the basis of the Akaike Information Criterion. The results of Wald tests suggest that for all time scales, for nearly all states, land rents do not Granger-cause (predict) land values. On the other hand, land values for some states Granger-cause land rents.

6. Conclusion

Land is by far the most important asset to the agricultural economic sector. Significant fluctuations in the price of farmland create non-negligible income risk, which has repercussions on agricultural finance issues and more generally creates hardship for rural communities. Although fundamentals such as inflation explain much of the boom/bust cycles and long run trends in rural land value, shorter-term volatility is more difficult to explain. One plausible explanation, speculative bubbles, has been found difficult to evaluate empirically. This paper uses wavelet-based statistical tools together with established econometric methods to show that a short-run speculative bubble in the real option value to land development may have been active in some years. As with all tests of the bubble hypothesis, however, we cannot reject the possibility of a model specification error.