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Farmland Prices: Is This Time Different?

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The historical behavior of farmland prices, rental rates, and rates of return are examined by treating farmland as an asset with an infinitely long life. It is found that high (low) farmland prices relative to rents have historically preceded extended periods of low (high) net rates of return, rather than greater (smaller) growth in rents. Our analysis shows that this attribute is shared with stocks and housing, and the financial literature provides ample evidence that other assets feature it as well. The long-run relationship linking farmland prices, rents, and rates of return is analyzed. Based on this relationship, we conclude that recent trends are unlikely to be sustainable. The study explores the expected paths that farmland prices and rates of return might follow if they were to eventually conform to the average values observed in the historical sample, and concludes with a discussion of the policy implications. Recommendations for policy makers include close monitoring of farmland lending practices and institutions to allow early identification of potential problems, and identifying in advance appropriate interventions in case recent farmland market trends were to suddenly change.

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Abstract

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FARMLAND PRICES: IS THIS TIME DIFFERENT?

The U.S. agricultural economy has experienced a noticeable boom over the past decade. An emergence in the demand for biofuels, and, in particular, a strong surge from foreign markets has had a major positive effect on the profitability of U.S. production agriculture. This has translated into a strong positive trend in cash rents for farmland, and an even more pronounced upward trend in farmland prices. For example, average cash rents in Iowa increased by 93% between 2003 and 2012, from $122/acre to $235/acre. Over the same period, the average price of Iowa farmland jumped from $2,010/acre to $7,000/acre, for a 248% increase.

In the last century there were two occasions when U.S. farmland prices exhibited major booms over a relatively short period of time, namely, the two decades that ended in 1920, and the decade that ended in 1981. Farmland prices in Iowa increased by 428% between 1900 and 1920, fueled by rising wheat prices and increasing wheat yields (Gleaser (2013)). Similarly, farmland prices shot up by 383% between 1972 and 1981, owed mainly to a strong surge in the real price of agricultural products, and also to inflationary expectations. Ominously, in both occasions, farmland prices suffered precipitous declines after prices peaked. For example, farmland prices fell by 71% between 1920 and 1933, and by 61% between 1981 and 1987.

The two 20th century boom-bust cycles in U.S. farmland prices were not without precedent, as there were at least four well-documented cycles that occurred in the 19th century. Increasing cotton prices greatly contributed to a boom in farmland prices in Alabama in the second half of the 1810s, which triggered their collapse between 1819 and 1820 (Gleaser (2013)). Cotton prices were also the culprit of both the surge in farmland prices in the Southern U.S. around the mid-1830s, as well as their ensuing downfall in the panic of 1837 (Nelson (2012)). The panic of 1853 was intrinsically linked to the bust that followed the boom in Kansas farmland prices (Calomiris (1991)). In 1893, a steep fall in the price of wheat, together with droughts, precipitated an agricultural crisis in Kansas and Nebraska (Calomiris (2008), Nelson (2012)).

Importantly, the steep fall in farmland prices that followed each boom was accompanied by substantial financial distress. This occurred because farmland is the main asset in U.S. production agriculture (Gloy *et al*., 2011). As such, its value is critical for the industry's financial situation. Given the bust that followed previous major run-ups in U.S. farmland prices, it seems of particular interest to assess the likelihood that prices will mirror the behavior in past cycles after the current boom is over.

The present study analyzes the historical behavior of U.S. farmland prices, rental rates, and rates of return with the tools developed by modern finance (e.g., Cochrane (2011)). Rather than focus on the idiosyncracies of farmland that arguably make it a unique type of input in the production process, we treat it as a standard asset with an infinitely long life. To assess the robustness of our findings concerning farmland, we supplement our analysis by examining the extent to which the behavioral patterns uncovered for farmland are shared with the prices and cash flows of two other major types of long-lived assets, namely U.S. stocks and U.S. housing.

Succinctly, we find strong evidence that high (low) farmland prices relative to rents have historically preceded extended periods of low (high) net rates of return, rather than greater (smaller) growth in rents. Our analysis shows that this attribute is shared with stocks and housing; importantly, a number of studies (see, e.g., citations in Cochrane (2009)) provide ample evidence that other assets feature it as well. We analyze the relationship that must link farmland prices, rents, and rates of return in the long-run, and conclude that the recent values observed for such variables are likely to be unsustainable. We also discuss the expected paths that farmland prices and rates of return might follow if they were to eventually conform to the average values observed in the historical sample. We conclude the study by addressing the policy implications of the empirical results.

1. Data

The basic series used for the analysis are annual observations on the nominal prices of the respective assets and their corresponding nominal annual net cash payouts. An asset's cash

payout is the stream of cash generated by the asset over a period of time. Cash payouts often receive specific designations, depending on the asset that generates them; thus, for example, they are labeled rents or rental payments in the case of real estate, dividends in the case of stocks, and interest or interest payments in the case of coupon bonds. For simplicity, and since the focus of the present study is farmland, cash payouts will be designated generically as "rents" in the remainder of the study.

For farmland, the nominal price is the per-acre value of cash-rented Iowa farm real estate, and the nominal net cash payouts are the corresponding gross cash rents minus property taxes calculated by the U.S. Department of Agriculture from survey data. Both series are the same as the ones used by Lence and Miller (1999), updated to cover the period 1900-2012 with data downloaded from the National Agricultural Statistics Service website (*http://nass.usda.gov/*).[1] Further details about the farmland series are found in Lence and Miller (1999, p. 264). It should be pointed out that both land price and rent data are based on farmers' subjective survey responses, which may make them prone to subjective biases. While such biases may introduce noise, it seems unlikely they can render the present empirical analysis invalid.[2]

For stocks, nominal prices and net cash payouts are the Standard & Poor's index and the corresponding dividends for the period 1871-2012. The series for stock prices and dividends are updated versions of the data shown in Shiller (Ch. 26, 1989; 2000), and were obtained from the website maintained by Shiller at *http://www.econ.yale.edu/~shiller/data.htm*. Shiller's website also provides detailed descriptions of the stock data. Finally, nominal prices and net cash payouts for housing consist of the first-quarter Case-Shiller-updated average house prices and imputed average annual house rents published by the Lincoln Institute of Land Policy. The housing series

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[1]The property tax value for 2012 was not available, so it was estimated by assuming that the property tax increased between 2011 and 2012 by the same percentage as the cash rent between those two years. This is unlikely to have any effect on the results because property taxes averaged only about 13% of cash rents between 2000 and 2011, and ranged between 11% and 15% over the same period.

[2]For example, the conclusions from our empirical analysis would remain unchanged if price or rent responses exhibited a consistent bias of, e.g. −10% of the "true" values. However, the conclusions could be significantly affected if, e.g. the bias were substantially volatile relative to the price or rent volatilities. *A priori*, real-world scenarios characterized by conditions like the latter are difficult to fathom.

cover 1960-2012, and are available at the institute's website:

http://www.lincolninst.edu/subcenters/land-values/.

Real prices for each year t ($Price_t$) were constructed by dividing the respective nominal series by the corresponding consumer price index. The latter was downloaded from the aforementioned Shiller's website as well. Real rents for each year t ($Rent_t$) were computed in an analogous manner.

Table 1 summarizes sample statistics for the price/rent ratio ($Price_t/Rent_t$),[3] the annual growth rate of prices, the annual growth rate of rents, and the annual net rate of return for each of the assets. Table 1.A shows that, on average, prices for farmland have been slightly over eighteen times (annual) rents. This figure is somewhat smaller than the analogous ones for stocks and housing, for which price/rent ratios averaged 26.0 and 20.6, respectively. For all three assets, the standard deviations of price/rent ratios are large, and especially so for stocks. Importantly, the first-order correlation coefficients for the price/rent ratio are close to unity (and for farmland is as high as 0.987), indicating a high degree of autocorrelation.

Table 1.A also shows that the point estimates of the annual growth rates in farmland prices and rents are 1.5% and 0.6%, respectively. Such figures are comparable to their counterparts for stocks (2% and 1.3%) and housing (1.2% and 0.9%). For each of the three assets, the standard deviation of growth rates for prices exceeds the one for rents. Stock (housing) prices have the growth rates with the highest (lowest) volatility and the lowest (highest) first-order autocorrelation. Interestingly, the average net rates of return for the three assets are quite similar, ranging between 6% per year for housing and 7% per year for farmland. However, the net rate of return has been more volatile and less autocorrelated for stocks (with a standard deviation of 17.5% per year, and a first-order autocorrelation of 0.028) than for farmland (standard deviation = 9.5% per year, first-order autocorrelation = 0.446), and much

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[3]For stocks, the ratio of asset prices to their net cash payouts is known as the price-dividend ratio (see, e.g. Cochrane (1992)). As noted earlier, the term "rents" is used to refer generically to cash payouts for the remainder of the paper because that is the designation used in the case of farmland.

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more so than for housing (standard deviation = 5.8% per year, first-order autocorrelation = 0.626). The sizable costs associated with the transactions of farmland and houses are a likely reason why the net rates of return for such assets exhibit substantially greater autocorrelation compared to stocks (Lence, 2003).

Table 1.B reports the correlation coefficients between contemporaneous series. By far, the highest within-asset correlation is the one between price growth rates and rates of return, which equals 0.99 for all three assets. In contrast, the within-asset correlations between price/rent ratios and rent growth rates, and between price/rent ratios and rates of return are negligible. Other within-asset correlations worthy of notice are the ones between price growth rates and rent growth rates, and between price growth rates and rates of return; such correlations are high for farmland (correlations equal 0.74) and stocks (correlations equal 0.63), but not for housing (correlations equal 0.20 and 0.24).

Overall, there is little evidence of high correlations across assets. The highest across-asset correlations correspond to price/rent ratios, with a correlation coefficient of 0.52 between housing and farmland, and 0.49 between housing and stocks, but only 0.10 between farmland and stocks. The small level of across-asset correlations is important for the present purposes: If across-asset correlations are low, empirical regularities shared across assets provide stronger support for the hypothesis that there exist general (i.e., non-idiosyncratic) behavioral patterns, than if across-asset correlations were high.[4]

2. The Present Value Model of Asset Pricing Revisited

The present value model of asset pricing has been the most widely used framework to guide discussions about asset prices, including the prices of farmland (see, e.g. Falk (1991) and Falk

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[4]To illustrate this point, suppose that the null hypothesis for a particular sample is rejected at the 1% significance level, and for another independent sample it is rejected at the 1% significance level, as well. Then, the probability of the two independent samples simultaneously rejecting the null hypothesis is only 0.01%.

and Lee (1998)). Succinctly, the time-*t* price of an asset can be expressed as the asset's fundamental value (*Fundamental_t*) plus a rational bubble (*Bubble_t*):[5]

(2.1) $Price_t = Fundamental_t + Bubble_t,$

The fundamental value is the "present value" of the asset's future rents, that is, the time-*t* expectations of the asset's future rents, appropriately discounted to account for the fact that they may be uncertain and will be received in the future. One of the most critical questions in the empirical asset pricing literature has been whether the price of an asset represents only fundamental value (so that $Bubble_t = 0$), or includes a bubble as well.

Unfortunately, the econometric analyses of equality (2.1) are plagued with identification problems that make it impossible to yield definitive answers without making strong assumptions. The essential problem is that asset prices and rents are the only observable variables; the discounting factor, the fundamental value, and the bubbles (if they do exist) are not observable. Thus, it is impossible to make inferences about whether or not historical asset price series contain bubbles without making strong assumptions about the behavior of the discounting factor (Gürkaynak, 2008). As shown next, this problem also arises when testing empirically for the existence of bubbles in farmland prices.

To illustrate the issues involved in testing for whether prices only reflect fundamental value, note that the fundamental/rent ratio (*Fundamental_t*/*Rent_t*) can be expressed as the expected sum of future gross rates of rent growth, appropriately discounted to the present (see equation (A.4) in Appendix A). This implies that the fundamental/rent ratio is stationary if the discounting factor and rent growth rates are both stationary (see, e.g., Theorem 3.34 in White (1982)). Further, given equality (2.1), the price/rent ratio must be stationary if the fundamental/rent ratio is stationary and there are no bubbles. Thus, finding that the price/rent ratio is non-stationary

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[5]The derivation of expression (2.1) and other implications of the present value model are provided in Appendix A.

may be construed as evidence of a bubble when both the discounting factor and the rent growth rate are stationary.

The discounting factor is not observable, but economic theory suggests that it should also be stationary.[6] Rents are observable, and historical time series for rent growth rates typically appear to be stationary. In contrast, empirical studies have often found evidence of non-stationary price/rent ratios, or alternatively that rents and prices are not cointegrated (see, e.g., references in Gürkaynak, 2008). Results of stationarity tests for farmland, stocks, and housing are shown in Table 2. The top three rows show clear evidence that rents are non-stationary. For all assets, the null hypothesis of stationary rents is soundly rejected, and the null hypothesis of a unit root cannot be rejected at standard levels of significance. In contrast, rent growth rates appear to be stationary, especially for farmland and stocks. The null hypothesis of a unit root in the rent growth rate series is strongly rejected, whereas the null hypothesis of stationarity cannot be rejected at typical significance levels for farmland and stocks (but is rejected at the 6% significance level for housing).

For the price/rent ratio, the evidence provided by stationarity and unit-root tests is definitely mixed. For farmland, the null hypothesis of a unit root cannot be rejected, but the null of stationarity cannot be rejected either. Housing is characterized by the opposite situation, with the null of a unit root strongly rejected, and the null of stationarity strongly rejected as well. The case of stocks is similar to the one for housing, with the null of a unit root rejected at the 6% level of significance, and the null of stationarity rejected at less than 1% significance level.

Price/rent ratios for farmland, stocks, and housing are depicted in Figure 1 to help visualize the substantial level of autocorrelation exhibited by the price/rent ratios reported in Table 1.A, and implied by the results in Table 2. It is clear from the graph that if the series shown have long-run means to which they tend to converge (as it should be the case if the series are stationary), such convergence occurs very slowly. The price/rent ratio for farmland shows

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[6]For example, in the consumption capital asset pricing model (Breeden, 1979) the discount rate consists of $\delta_{t+1} = U'(c_{t+1}, t+1)/U'(c_t, t)$, where $U'(c_t, t)$ is the marginal utility of consumption at date t (c_t).

three peaks, one in 1920 at 30.5, another in 1980 at 20.7, and another one in 2012 (the latest observation in the sample) at 34.1. Recent price/rent ratios for farmland seem unusually high by historical standards, and the most recent observation is the highest one recorded over the 113-year sample. The lowest price/rent ratios for farmland were observed in 1900 and 1986 when price was slightly less than twelve times rents. Price/rent ratios for stocks have been considerably more volatile than for farmland (see Table 1.A). Further, since around the mid-1990s stock price/rent ratios values have always been above the highest values achieved over the previous century. For housing, price/rent ratios peaked in 2007 at a value of 35.6, and fell afterwards to 20.1 in 2012.

Differences between the results of stationarity tests for rent growth rates and rent/price ratios, such as the ones illustrated by Table 2, have prompted some researchers to conclude that asset prices are likely to include bubbles (see, e.g., references in Gürkaynak, 2008). Indeed, the substantially greater autocorrelation of price/rent ratios compared to rent growth rates evident in Tables 1 and 2 soundly rejects the hypothesis of a constant-discount rate present value model (i.e., asset prices being equal to the expected future rents discounted at a constant rate). However, other researchers have been more reluctant to dismiss the hypothesis that asset prices only reflect fundamental value, showing that it can still hold under appropriate assumptions (Gürkaynak, 2008). The power of empirical tests to provide an answer regarding the existence of bubbles in asset prices is further weakened by the results in Evans (1991). He has shown that under realistic circumstances, empirical tests of asset prices including bubbles may lead to the incorrect inference that their rent/price ratios are stationary.

In summary, the unobservability of the discount factor, coupled with the inability of empirical tests to discern whether highly autocorrelated time series are stationary or not,[7] poses a

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[7]This point is forcefully made by Cochrane (1991, p. 275): "Since the random walk component can have arbitrarily small variance, tests for unit roots or trend stationarity have arbitrarily low power in finite samples. Furthermore, there are unit root processes whose likelihood functions and autocorrelation functions are arbitrarily close to those of any given stationary processes and vice versa, so there are stationary and unit root processes for which the result of any inference is arbitrarily close in finite samples."

fundamental identification problem to answer the question of whether asset prices only reflect fundamental values. For this reason, this issue is not pursued any further in the present study. Instead, the analysis in the next sections relies on a mathematical identity involving the price/rent ratio to uncover some asset pricing regularities exhibited by farmland, stocks, and housing, as well as other assets not studied here (see, e.g., Cochrane, 2011, pp. 1051-1052). The analysis holds regardless of whether asset prices are rationally established. However, the stationarity of price/rent ratios is relevant even for this endeavor, because the ensuing analysis assumes they are stationary.

As pointed out earlier in connection with Table 2, the empirical evidence regarding the stationarity of the price/rent ratio for farmland is mixed. However, taken at face value, a non-stationary price/rent ratio means that it can become arbitrarily large or small, and that its unconditional variance is infinite. Such implications of non-stationary price/rent ratios are difficult to rationalize and reconcile with economic fundamentals. Thus, we proceed with the analysis by adhering to Cochrane's (2008) argument in favor of assuming stationary price/rent ratios.

3. The Predictive Ability of Price/Rent Ratios

Instead of focusing on the rationality of asset values, a number of recent empirical studies in finance have instead shifted attention to the ability of price/rent ratios to forecast the subsequent behavior of asset-related variables (see, e.g., Cochrane (2008, 2011). This rapidly-growing literature is based on the fact that, regardless of whether asset prices are rationally established or not, price/rent ratios must forecast future rates of return, future rent growth, future price/rent ratios, or some combination thereof. The premise of these studies is that, even if asset price behavior falls short of full rationality, it is useful to know whether, e.g. relatively high price/rent ratios have typically been followed by high rates of rent growth, low rates of return, or high price/rent ratios.

The fact that price/rent ratios must forecast future rent growth, future rates of return, or future price/rent ratios can be easily demonstrated. To this end, multiply and divide the period-t price/rent ratio by prices and rents corresponding to period $(t + 1)$, while leaving the ratio unchanged, as follows:

$$(3.1) \quad \frac{Price_t}{Rent_t} = \frac{Rent_{t+1}}{Rent_t} \times \frac{1}{\dfrac{Price_{t+1} + Rent_{t+1}}{Price_t}} \times \left(\frac{Price_{t+1}}{Rent_{t+1}} + 1 \right).$$

Since the period-$(t + 1)$ prices and rents on the right-hand side of equation (3.1) cancel with each other, the term to the right of the equality sign simplifies to the period-t price/rent ratio. The first term on the right-hand side is the gross growth rate of the asset's rent between periods t and $(t + 1)$. The denominator in the second term is the asset's gross rate of return between periods t and $(t + 1)$. Finally, the third term is the period-$(t + 1)$ price/rent ratio augmented by one.

According to identity (3.1), if the price/rent ratio on a particular period is high, it must be followed by a high rent growth, a low rate of return, a high price/rent ratio, or a combination thereof. Equation (3.1) is a mathematical identity, and as such it is always satisfied by the data *ex-post*. This means that it holds regardless of any assumption made about the underlying economic model driving the behavior of prices, rents, or rates of return.

Equation (3.1) may be a trivial mathematical identity, but it has been cleverly exploited by researchers in finance to analyze whether historically high (low) price/rent ratios have tended to predict high (low) rent growth, low (high) rates of return, high (low) price ratios, or a combination thereof in subsequent years. More specifically, assuming that the price/rent ratio is stationary, it can be shown that the log-price/rent ratio in year t is approximately equal to a constant plus the sum of the following three terms:

1. A weighted average the net rates of rent growth over J years after year t;
2. A weighted average of the negative of the net rates of return over J years after year t;

3. A fraction of the log-price/rent ratio in year $(t + J)$, which diminishes with J and tends to zero as J becomes large.

The exact form of this relationship and its derivation are provided in Appendix B.

For example, if we set a horizon of $J = 15$ years into the future, the logarithm of the farmland price/rent ratio of 34.1 observed in 2012 must be equal to a constant plus a weighted average of farmland's annual net rates of rent growth over 2012-2027, minus a weighted average of farmland's annual net rates of return between 2012 and 2027, plus a fraction of the price/rent ratio in year 2027. In other words, if the 2012 farmland price/rent ratio is high, then the growth rate of farmland rents over 2012-2027 must be high, or the rate of return to farmland over the same period must be low, or the 2027 price/rent ratio must be high, or a combination of such outcomes must hold. Of course, at this point it is unknown which of the aforementioned outcomes will actually occur between 2012 and the year 2027. However, it is possible to look back at the historical record to assess which outcome(s) farmland price/rent ratios was most likely to predict over $J = 15$-year horizons, and then use those results to make inferences about the probabilities of the alternative scenarios over the period 2012-2027.

The method for performing the aforementioned inferences was introduced in a pioneering article by Cochrane (2008). He demonstrated that since in any particular year the observed price/rent ratio must be associated with rent growth rates or rates of return over the following J-year horizon, or the price/rent ratio after J years, or a combination of such variables, the predictive ability of the price/rent ratio must satisfy the following approximate decomposition:[8]

$$
(3.2) \quad \underbrace{\begin{bmatrix} Price \ / \ Rent \ Ratio's \\ Ability \ to \ Forecast \\ Rent \ Growth \ Rates \\ Over \ Next \ J \ Years \end{bmatrix}}_{\beta_{Rent}^{(J)}} + \underbrace{\begin{bmatrix} Price \ / \ Rent \ Ratio's \\ Ability \ to \ Forecast \\ Rates \ of \ Return \\ Over \ Next \ J \ Years \end{bmatrix}}_{\beta_{Return}^{(J)}} + \underbrace{\begin{bmatrix} Price \ / \ Rent \ Ratio's \\ Ability \ to \ Forecast \\ Price \ / \ Rent \ Ratio \\ J \ Years \ Ahead \end{bmatrix}}_{\beta_{P/R}^{(J)}} \cong 1.
$$

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[8]The derivation of decomposition (3.2) is shown in Appendix B.

In this expression, the first term ($\beta_{Rent}^{(J)}$) can be estimated as the coefficient computed by running an ordinary least squares (OLS) regression of the weighted averages of the annual net rates of rent growth over *J*-year horizons against the immediately preceding log-price/rent ratios. Similarly, an estimate of the second term ($\beta_{Return}^{(J)}$) is <u>the negative of</u> the OLS slope coefficient obtained by regressing the weighted averages of the annual net rates of return over *J*-year horizons against the immediately preceding log-price/rent ratios. Finally, an estimate of the third term ($\beta_{P/R}^{(J)}$) can be calculated from the OLS slope coefficient corresponding to the regression of the log-price/rent ratio against the log-price/rent ratio *J* years earlier.

Decomposition (3.2) is useful because it allows one to attribute the large observed historical variability in price/rent ratios to three basic sources, namely, variability in the subsequent *J*-year horizon rent growth ($\beta_{Rent}^{(J)}$), variability in the subsequent *J*-year horizon rate of return ($\beta_{Return}^{(J)}$), and variability in the price/rent ratio *J* years later ($\beta_{P/R}^{(J)}$). Put another way, the polar case of $\beta_{Rent}^{(J)} = 1$ and $\beta_{Return}^{(J)} = \beta_{P/R}^{(J)} = 0$ means that price/rent ratios have forecasted rent growth rates, but have not forecasted rates of return or price/rent ratios. The alternative polar case of $\beta_{Return}^{(J)} = 1$ and $\beta_{Rent}^{(J)} = \beta_{P/R}^{(J)} = 0$ implies that price/rent ratios have predicted rates of return, but have predicted neither rent growth rates nor price/rent ratios. The final polar case of $\beta_{P/R}^{(J)} = 1$ and $\beta_{Rent}^{(J)} = \beta_{Return}^{(J)} = 0$ represents a bubble, as price/rent ratios are neither driven by rent growth rates nor rates of return, but only future price/rent ratios.

OLS estimates of decomposition (3.2) for horizons ranging from *J* = 1 year through *J* = 20 years are reported in columns three through five in Table 3. The most interesting finding is that, over long horizons, variability in price/rent ratios is mainly associated with variability in the subsequent rate of return for all three assets. In other words, for farmland as well as stocks and housing, high (low) price/rent ratios have predicted low (high) rates of return rather than low (high) rent growth. The empirical evidence also indicates that for the three assets, rent growth rate predictions from price/rent ratios bear the wrong sign for horizons of *J* = 10 years or longer. This result is unexpected, because *ceteris paribus* higher price/rent ratios should signal higher (as opposed to lower) future rent growth (see, e.g., identity (3.1)). In addition, the negligible value of

the long-horizon $\beta_{P/R}^{(J)}$ estimates provides little support for the hypothesis of a bubble for either asset.

Figure 2 provides a pictorial representation of the historical behaviors of the logarithm of farmland price/rent ratios and the negative of the weighted sum of subsequent net rates of return are represented pictorially (note the differences in scale for the two variables). The graph provides a visual confirmation of the close association between the two variables underlying the OLS estimates of $\beta_{Return}^{(J)}$ shown in Table 3. Analogous graphs for stocks and housing are omitted in the interest of space, but they reveal a similar association between the log-price/rent ratios and the negative of the weighted sum of subsequent net rates of return.

To assess the robustness of the OLS estimates of decomposition (3.2), we also computed the decomposition implied by a vector autoregression (VAR). Succinctly, rather than estimating the coefficients in decomposition (3.2) directly by OLS, we estimated a VAR, and used the resulting parameter estimates to calculate the desired coefficient estimates by forward iteration.[9] The VAR-based decomposition is shown in the last three columns of Table 3. They confirm the OLS findings that high (low) price/rent ratios have largely predicted low (high) rates of return, as opposed to high (low) rent growth rates. The main difference between the OLS and VAR-based decompositions is that the latter bear the correct signs (i.e., positive) at all horizons for stocks.

The finding that price/rent ratios for farmland, stocks, and housing have predicted rates of return, as opposed to rent growth rates (or price/rent ratios), is consistent with the results of studies that analyzed other assets. The latter assets include Treasury securities (Fama and Bliss, 1987; Campbell and Shiller, 1991; Piazzesi and Swanson, 2008), bonds (Fama, 1986; Duffie and Berndt, 2011), foreign exchange (Hansen and Hodrick, 1980; Fama, 1984), and sovereign debt (Gourinchas and Rey, 2007). The fact that price/rent ratios appear to predict rates of return for a large number of assets lends support to the notion that our finding for farmland is robust, and indicative a general feature shared with many assets.

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[9]Details of the computation of the decomposition coefficients from the VAR parameter estimates are provided in footnote b of Table 3.

In summary, it is safe to conclude that the historical record for farmland is similar to that of other assets, in that it provides strong evidence that high (low) price/rent ratios have been subsequently followed by low (high) rates of return, instead of low (high) rates of growth in rents. If the past gives any indication about the future, the record high price/rent ratios observed in recent years are not a good omen regarding future rates of return to farmland.

4. Price/Rent Ratios in the Long Run: The Tyranny of Mathematical Identities

Stationary price/rent ratios imply the existence of a long-run value to which price/rent ratios tend to converge whenever they are different from such long-run value. Since this also implies that future price/rent ratios will tend to converge to the same value in the long run, it must be the case that prices and rents must grow at the same rate in the long run.[10] That is, when price/rent ratios are stationary, on average asset prices must grow at the same rate as rents. The converse is also true: Price/rent ratios must be non-stationary if the long-run mean growth rate is different for asset prices compared to rents.

Point estimates of the mean growth rates of prices and rents for the entire samples are reported in Table 1. The mean price growth rate estimates are larger than the mean rent growth estimates for all three assets. However, the null hypothesis that the mean growth rates are the same for prices and rents cannot be rejected at reasonable significance levels for any of the assets. In short, the data available are consistent with mean price growth rates being the same as mean rent growth rates for the historical samples under study.

The fact that stationary price/rent ratios imply that prices and rents must grow at the same rate in the long run can be used to put the recent growth in farmland prices in perspective. According to Table 4, farmland prices grew at an average annual rate of 10.6% between 2003 and 2012, which was more than double the average annual rent growth rate of 4.5% over the

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[10]To prove this point, note that stationary price/rent ratios imply that $E[log(Price_{t+j}/Rent_{t+j})] = E[log(Price_t/Rent_t)]$ $\forall$ j, where $E(\cdot)$ denotes the unconditional expectation operator. Since such equality implies $E[log(Price_{t+j}/Rent_{t+j}) - log(Price_t/Rent_t)] = 0$ $\forall$ j, it follows immediately that $E[log(Price_{t+j}/Price_t)] = E[log(Rent_{t+j}/Rent_t)]$ $\forall$ j, as claimed.

same period. Interestingly, Table 4 also shows that the growth rates experienced by farmland prices and rents between 2003 and 2012 were unusually high by historical standards. For example, between 1900 and 2002, annual growth rates averaged only 0.6% for prices and 0.2% for rents.

Noticeably, 2003-2012 was the ten-year period with the highest average price growth rate since the sample started in 1900. The decade with the second-highest average price growth rate was 1972-1981, when prices rose at an average rate of 8.0% per year. In the case of rents, the only time the average growth rate exceeded the average recorded over 2003-2012 for two consecutive five-year intervals was the 1965-1974 decade, when rents increased by an average of 5.7% per year. The 2003-2012 period was also the decade with the highest average net rate of return to farmland (14.4% per year). The ten-year period with the second highest average net rate of return was the 1972-1981 boom (14.0% per year).[11]

With prices and rents growing at the same rate over the long run, even if one were to assume that over the foreseeable future (a) rents will keep growing at the historically high rate of 4.5% per year recorded in 2003-2012, and (b) the price/rent ratio will remain at the record high level of $Price_t/Rent_t = 34.1$ observed in 2012, the annual growth rate in farmland prices would have to eventually fall significantly relative to the recent past (i.e., from 10.6% to 4.5% per year). If the long-run future rent growth rate and price/rent ratio are more in line with historical levels than with the values observed in recent years, the eventual decline in the long-run future growth rate of farmland prices will have to be far more dramatic.

Under the assumption that price/rent ratios are stationary, identity (3.1) can also be used to analyze some interesting relationships that must hold in the long run. More specifically, it can be shown that the long-run net rate of return must be approximately equal to the long-run net rate

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[11]The average real net rate of return for both periods was far greater than the corresponding short-term real interest rates. An anonymous reviewer has pointed out that the non-bubble view of current farmland prices is largely based on the opinion that very low (nominal) interest rates justify the high price/rent ratios being observed. This was not the case in the land value boom that ended in the early 1980s, because nominal interest rates were quite high at the time.

of growth in rents, plus a positive function of the long-run log-price/rent ratio and the variance of the log-price/rent ratio.[12] This relationship implies that the net rate of return must exceed the net rate of rent growth over the long run. Further, since stationary price/rent ratios imply that prices must grow at the same rate as rents in the long-run, it also follows that the net rate of return must be greater than the net rate of price growth over the long run.

The aforementioned inequalities are strongly supported by the sample data shown in Table 1. The point estimates of the lung-run net rate of return are greater than the point estimates of the lung-run net rate of growth in rents (e.g., 7.0% versus 0.6% per year for farmland), and the null hypothesis that the two long-run rates are equal is rejected for each of the assets at significance levels smaller than 0.1%. The data reported in Table 1 also provide strong support for the hypothesis that the net rate of return exceeds the net rate of price growth in the long run, as all point estimates satisfy it, and the null hypothesis that the long-run rates are the same is rejected at levels of significance below 0.1% for each of the assets.

Figure 3 illustrates how the long-run relationship among the rate of return, the rate of rent growth, the price/rent ratio, and the variance of the price/rent ratio can be applied to analyze the case of farmland. The graph depicts the long-run net rate of return as a function of the long-run log-price/rent ratio dictated by such relationship. All curves are drawn by fixing the variance of the log-price/rent ratio at the sample value corresponding to the period 1900-2002, i.e., 0.19^2 (see Table 4). The thick curve surrounded by the two dashed curves is drawn by setting the net rate of growth in rents equal to 0.2% per year, which is the average rate observed between 1900 and

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[12]The concrete expression for the approximate long-run association is

$$E\{log[(Price_{t+1}+Rent_{t+1})/Price_t]\} = E[log(Rent_{t+1}/Rent_t)] + log[1 + exp(-\mu_{P/R})] + \frac{1}{2} \frac{exp(\mu_{P/R})}{[1 + exp(\mu_{P/R})]^2} \sigma^2_{P/R},$$

where $E(\cdot)$ denotes the unconditional expectation operator, $exp(\cdot)$ is the exponential function, $\mu_{P/R} = E[log(Price_t/Rent_t)]$ is the unconditional expectation of the log-price/rent ratio, and $\sigma^2_{P/R} = var[log(Price_t/Rent_t)]$ is the unconditional variance of the log-price/rent ratio. This relationship is obtained by taking logarithms on both sides of equation (3.1), performing a second-order Taylor expansion of $log(Price_{t+1}/Rent_{t+1} + 1)$ around $\mu_{P/R}$, taking unconditional expectations, and rearranging the resulting expression.

2002 (see Table 4). The upper (lower) dashed curve assumes instead that the mean net rate of rent growth is equal to the upper (lower) bound of the estimated 95% confidence interval for mean rent growth rate based on 1900-2002 data, or 1.6% (-1.3%) per year. The filled circle represents the average values of net rate of return and log-price/rent ratios corresponding to the 1900-2002 period. The fact that this circle is very close to the thick curve and well within the dashed curves provides evidence that the sample data over 1900-2002 are consistent with the postulated long-run relationship.[13]

The thick curve shows the net rate of return that can be expected over the long run for different long-run values of log-price/rent ratios, assuming that rents will grow by 0.2% per year over the long run (and that the variance of the log-price/rent ratio will be 0.19^2). For example, the long-run net rate of return will be 9.0% per year if the log-price/rent ratio averages 2.4 over the long run, but it will only be 2.9% per year if the long-run log-price/rent ratio averages equals 3.6. The fundamental insight from the long-run relationship shown in the graph is that, for a given long-run growth rate in rents, the long-run net rate of return will be high only if the price/rent ratio is small over the long run.

To put recent developments in the farmland market in perspective, Figure 3 also shows the long-run relationship, assuming the average net rate of rent growth observed over 2003-2012 (i.e., 4.5% per year, see Table 4), depicted as the thin line. In addition, the combination of average net rate of return and average log-price/rent ratio for 2003-2012 is included as the filled square, and the combination of the net rate of return and log-price/rent ratio for 2012 is drawn as the filled diamond. The position of the latter points relative to the long-run curves suggests that combinations of net rate of return and price/rent ratios observed over the most recent decade are not sustainable in the long run, unless rents grow over the foreseeable future at rates well above

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[13]Graphs analogous to Figure 3 for stocks and housing are omitted in the interest of space, but they provide very strong support that the postulated long-run association among the net rate of return, the net rate of rent growth, the price/rent ratio, and the variance of the price/rent ratio holds also for stocks and housing over their corresponding historical samples.

what has been observed in the past (even considering the high average rent growth rates recorded over 2003-2012).

4.1. What Path to the Long Run?

So far, the discussion has focused around the long run. Of obvious interest is what may happen over the nearer future since, as pointed out by Keynes, "In the long run we are all dead." Unfortunately, such type of analysis is subject to great uncertainty, as made clear by the high volatility that characterizes the price/rent ratio (see Figure 1). However, even if it is not possible to forecast the short run with much accuracy, it may still be useful, for some purposes, to learn more about what might happen "on average." That is, if it were possible to perform an experiment consisting of repeating the near future many times, beginning from the same fixed starting point, what would the average outcome be?

The mathematical identity (3.1) can be used again to shed some light about the average paths that farmland prices and rates of return may be expected to follow in a nearer future. To this end, it is necessary to supplement the logarithm of identity (3.1) with two additional equations, labeled "equations of motion," specifying dynamic relationships among rent growth rates, rates of return, and price/rent ratios. The logarithm of identity (3.1) plus the two equations of motion provide three equations in the three unknown logarithmic variables rent growth rate, rate of return, and price/rent ratio. The expected path of such variables over time can then be obtained by forward iteration based on those three equations. Finally, the expected price growth path can be computed by adding the expected growth in the price/rent ratio to the expected rate of rent growth.[14]

The critical issue for the analysis is the specification of the two equations of motion chosen to supplement identity (3.1), for two reasons. First, implicit in such equations are the long-run values. In other words, different equations of motion translate into different long-run

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[14]Note that $log(Price_{t+1}/Price_t) = log(Rent_{t+1}/Rent_t) + log[(Price_{t+1}/Rent_{t+1})/(Price_t/Rent_t)]$.

behaviors. Second, the equations of motion determine the average paths from the starting point to the long-run values. As illustrated forcefully by the example below, changing the specification of the equations of motion can have a striking short-run impact, even if one were to leave the long-run values unchanged.

To make matters concrete, we illustrate the expected paths for the case where the starting point is the observed 2012 occurrence, and the long run is represented by the average outcomes over 1900-2002. That is, we compute the paths that, on average, might lead from the filled diamond to the filled circle drawn in Figure 3.[15]

The first equation of motion is assumed to have the same slope coefficients as the slopes estimated from an analogous OLS regression, using data for the period 1900-2002. Such regression has a very good fit ($R^2 = 0.920$), and all of its slope estimates are different from zero at standard significance levels (see Appendix C for details). For the second equation of motion, two alternative specifications are adopted to highlight the impact that such equations can have on the expected paths. For reasons that will become obvious shortly, the alternative specifications are denoted as "Hard Landing" (HL) and "Soft Landing" (SL) scenarios.

In the HL scenario, the slopes of the second equation of motion are also identical to the slopes of an analogous OLS regression estimated with data for 1900-2002 (see Appendix C for details). This second regression also has a good fit ($R^2 = 0.277$), and two of its slopes are significantly different from zero at less than the 1% level, while the third slope is significantly different from zero at the 5.5% level. By construction, the HL scenario is consistent with the historical data over 1900-2002. This implies that, as discussed in Section 3:

HL1. Variability in the price/rent ratios is associated with variability in the subsequent rates of return, as opposed to variability in the subsequent rent growth, and;

HL2. High (low) price/rent ratios predict low (high) subsequent rates of return, rather than low (high) subsequent rent growth.

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[15]Of course, modifying the starting point or the long-run values will yield different paths.

To contrast with the above HL features, the second equation of motion for the SL scenario is set to represent the opposite situation, i.e.,

SL1. Variability in price/rent ratios arises from variability in the subsequent rent growth, instead of variability in subsequent rates of return, and;

SL2. High (low) price/rent ratios forecast low (high) subsequent rent growth, as opposed to low (high) subsequent rates of return.

Importantly, the features just listed are not supported by the historical data. Therefore, the slopes of the second equation of motion for the SL scenario are not consistent with the analogous OLS coefficients estimated with 1900-2002 data (see Appendix C for details). Instead, the second equation of motion for the SL scenario was constructed to ensure that properties (SL1) and (SL2) above are achieved.

Figure 4 shows the expected paths for the price growth rate and the rate of return under the HL and SL scenarios over a 30-year horizon.[16] By construction, the two scenarios lead to the same long-run annual rate of price growth (0.4%) and net rate of return (6.3%). However, the paths to get there under SL are strikingly different from the ones under HL. The SL paths are characterized by a slow but steady decline in the price growth rate and the net rate of return before stabilizing at their respective long-run values around years 15 and 7, respectively. In contrast, the HL paths have sharp declines, involving both negative price growth rates and negative rates of return over a number of years, before eventually stabilizing around year 20 by reaching their long-run values from below. Under the HL scenario, as a result of the long string of years with negative growth, prices bottom out after 17 years, at about 45% of the initial value.

As pointed out before, the HL scenario shows the paths that price growth rates and net rates of return would be expected to follow if, in the long run, they were to reach the average

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[16]It is worth repeating the meaning of the curves depicted in Figure 4: They represent the average outcome from running a hypothetical experiment, consisting of drawing a large number of individual random paths starting from the same initial point. Individual paths may be substantially different from the average, because the equations of motion have stochastic residuals with large standard deviations. This implies that the actual path observed in the future may depart noticeably from the curves in the graph.

levels observed over 1900-2002, and their dynamics were described by the behavior observed over that historical period as well. An obvious concern with the HR scenario is that net rates of return are expected to be negative over a number of years, which is difficult to reconcile with rational expectations (i.e., why would rational agents hold an asset with an expected negative rate of return?). The SL scenario has the advantage of not exhibiting the latter questionable feature; however, it is glaringly at odds with the historical record.

5. Summary and Policy Implications

The present study shows that the price/rent ratio for farmland, similar to the one for stocks and housing, has historically been characterized by a very strong autocorrelation. This means that if the price/rent ratio tends to revert back toward a long-run value, it does so very slowly. The present analysis also demonstrates that recent trends in farmland prices, rents, and net rates of return have been quite unusual by historical standards. If there is a long-run price/rent ratio for farmland, those trends do not seem to be sustainable in the long run, unless future rents were to keep rising at an extremely high rate for the foreseeable future. On the other hand, if there isn't a long-run price/rent ratio for farmland, economic theory indicates that fundamentals are not the only force driving the behavior of farmland prices.

The econometric results suggest that the historical behavior of U.S. farmland prices and rents has been consistent with that of other long-lived assets, namely, stocks and housing, in that high (low) price/rent ratios have been followed by extended periods of low (high) rates of return, as opposed to high (low) rates of growth in rents. Importantly, this finding is consistent with the empirical results from studies focusing on other types of assets, ranging from foreign currencies to government and corporate debt.

The present analysis also shows that there are important implications associated with whether high (low) price/rent ratios precede low (high) rates of return or high (low) rent growth. In particular, if there is a long-run price/rent ratio for farmland, the two alternatives imply that prices and rates of return are expected to follow very different paths as they approach the long-

run relationship that must hold among price/rent ratios, rates of return, and rent growth rates. To illustrate this point, an example is drawn under the assumption that farmland price/rent ratios, rates of return, and rent growth rates eventually return to their historical average values. In the scenario where the negative relationship between price/rent ratios and subsequent rates of return that has characterized the historical data for farmland (and other assets) is assumed to hold in the future, expected prices and rates of return suffer a "hard landing" involving noticeable falls before resuming long-run trends. In contrast, the scenario where price/rent ratios are hypothesized to be positively associated with subsequent rent growth, prices and rates of return experience a "soft landing:" the average price growth rate and the average rate of return decline slowly and steadily as they approach long-run values. Of course, a soft-landing would be much less stressful than a hard one, but the key assumption underlying is distinctively at odds with the historical record.

Are farmland prices different this time? In some respects, they are. In 2012, the ratio of prices to rents for Iowa farmland was the highest in the sample starting in 1900. Further, over the most recent decade the average growth in prices and rents, as well as the average net rate of return, has been the highest for any decade in the historical sample. In other respects, however, farmland prices are probably not any different this time: it seems premature to infer that just because such values have been observed in the recent past, they can be sustained for the foreseeable future.

From a policy standpoint, the key question is whether recent developments in farmland markets warrant action. In this regard, the implications of changes in the general level of asset prices for monetary policy have been examined by numerous studies (see, e.g., works included in Hunter, Kaufman, and Pomerleano (2003)). Cechetti (2006) provides a succinct overview of the main policy alternatives. Blejer (2007) summarizes the positions in this issue as consisting of a "conventional view" and an "extra-action view." According to the conventional view, changes in asset prices do not justify changes in monetary policy, unless they reflect changes in expected inflation or are likely to affect future output. Under this view, policy makers' efforts should

concentrate on alleviating the adverse consequences of significant falls in asset prices. The extra action view, in contrast, asserts that policy should systematically respond to developments in asset markets to avoid excessive increases in asset prices.

There are major advantages and disadvantages associated with both policy views (Blejer (2007)). The main limitations of the extra-action view are (a) the difficulty of identifying excessive asset price increases in a timely manner; and (b) the potential bluntness of the policy tools (e.g., interest rates). The empirical analysis provided in earlier sections shows that recognizing unusual increases in asset prices at a sufficiently early stage to take policy actions is not an easy task. Support for the extra-action view is additionally weakened when the unusual price developments are restricted to narrow classes of assets such as farmland, in which case general policy instruments like interest rates are difficult to justify.

However, our empirical analysis suggests that some narrowly targeted policies might be sensible. For example, tighter monitoring of the Farm Credit System in regard to farmland mortgages, and additional scrutiny of financial institutions to avoid the relaxation of collateral and lending standards for farmland loans, or the offering of farmland loans with creative terms or repayment schedules, appear to be reasonable regulatory actions.

It also seems sensible for policy makers to expedite the identification of the likely consequences associated with a reversion of recent farmland market trends. In doing so, they would be better prepared to intervene in a timely manner if policy actions could be taken to soften the negative impact of adverse market developments. Although at this time, the financial positions of the farm production sector and its lenders look stronger than they did at the onset of the most recent price bust (Briggeman), it would not be wise to underestimate the potential for a fallout in farmland prices to create havoc in the agricultural sector and the rural economies.

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Appendix A

According to the fundamental asset pricing equation (A.1) (Cochrane, 2001), the price of any asset at time t ($Price_t$) is given by the conditional expectation of the sum of its future payoff ($Rent_{t+1} + Price_{t+1}$) discounted at the appropriate discount rate (δ_{t+1}):

(A.1) $Price_t = E[\delta_{t+1} (Rent_{t+1} + Price_{t+1})|\Omega_t]$,

where $E(\cdot| \Omega_t)$ represents the expectation operator conditional on date t's information set Ω_t. By iterating (A.1) forward, the price of an infinitely long-lived asset can be written as:

(A.2) $Price_t = lim_{J\to\infty}\{E[\sum_{j=1}^{J} (\prod_{i=1}^{j} \delta_{t+i}) Rent_{t+j}| \Omega_t]\} + lim_{J\to\infty}[E(\prod_{i=1}^{J} \delta_{t+i} Price_{t+J}| \Omega_t)]$.

Equality (2.1) follows immediately, by defining variables *Fundamental_t* and *Bubble_t* respectively as the first and second terms on the right-hand side of equation (A.2).

By definition, $Bubble_t > 0$ if the expected discounted price far into the future does not tend to zero, in which case the current price contains a rational bubble. The current value of the latter must reflect its expected discounted value, i.e.,

(A.3) $Bubble_t = E(\delta_{t+1} Bubble_{t+1}| \Omega_t) = lim_{J\to\infty}E(\prod_{i=1}^{J} \delta_{t+i} Bubble_{t+J}| \Omega_t) > 0$.

In contrast, $Bubble_t = 0$ if the expected discounted price far into the future does equal zero. In this instance, the current price only reflects the asset's fundamental value (Craine, 1993).

Using the definition of fundamental value, the fundamental/rent ratio can be expressed as the expected discounted stream of gross rent growth rates:

$$(A.4) \quad \frac{Fundamental_t}{Rent_t} = lim_{J \to \infty} E[\sum_{j=1}^{J} (\prod_{i=1}^{j} \delta_{t+i} \frac{Rent_{t+i}}{Rent_{t+i-1}}) \mid \Omega_t].$$

Appendix B

By taking the natural logarithms on both sides of equation (3.1), and assuming that the price/rent ratio is stationary, Campbell and Shiller (1988) proved that the linear relationship,

$$(B.1) \quad log(Price_t/Rent_t) \cong \kappa + NetRentGrowth_{t+1} - NetReturn_{t+1} + \rho \, log(Price_{t+1}/Rent_{t+1}),$$

is an excellent approximation. In (B.1), κ and ρ are constants of approximation, variable $NetRentGrowth_{t+1} = log(Rent_{t+1}/Rent_t)$ is the net rate of growth in the asset's rents between times t and $(t + 1)$, and variable $NetReturn_{t+1} = log[(Price_{t+1}+Rent_{t+1})/Price_t]$ is the asset's net rate of return between times t and $(t + 1)$. Constant $\rho = exp(\mu_{P/R})/[1 + exp(\mu_{P/R})]$ is a function of the exponential ($exp(\cdot)$) of the unconditional expectation of the log-price/rent ratio $\mu_{P/R} = E[log(Price_t/Rent_t)]$, and constant κ is defined as $\kappa = (\rho - 1) \, \mu_{P/R} + log(\rho)$.

Iterating expression (B.1) forward on $log(Price_{t+1}/Rent_{t+1})$, the log-price/rent ratio can be expressed as:

$$(B.2) \quad log(Price_t/Rent_t) \cong \kappa \, \frac{(1-\rho^{J+1})}{1-\rho} + \sum_{j=1}^{J} \rho^j \, NetRentGrowth_{t+j}$$

$$- \sum_{j=1}^{J} \rho^j \, NetReturn_{t+j} + \rho^J \, log(Price_{t+J}/Rent_{t+J}).$$

That is, the date-t log-price ratio is equal to a constant, plus (a) a weighted average the logarithm of rent growth over J years after year t, minus (b) a weighted average of the logarithm of rates of return over J years after year t, plus (c) a fraction of the log-price/rent ratio in year $(t + J)$. Campbell and Shiller (1988) showed that equation (B.2) is a dynamic version of the Gordon (1962) model, and used it to test for alternative specifications of the discount factor.[17]

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[17]In particular, they tested the null hypotheses that the discount factor is equal to (a) a constant, (b) the short-term risk-free rate plus a constant risk premium, (c) a linear function of aggregate consumption, and (d) a linear function of the variance of the rate of return on stocks.

Cochrane (2008) noted that (B.2) implies that the variance of the log-price ratio must satisfy the following relationship:

(B.3) $\quad var[log(Price_t/Rent_t)] = cov[log(Price_t/Rent_t), log(Price_t/Rent_t)]$

$$\cong cov[log(Price_t/Rent_t), \sum_{j=1}^{J} \rho^j\ NetRentGrowth_{t+j}]$$

$$- cov[log(Price_t/Rent_t), \sum_{j=1}^{J} \rho^j\ NetReturn_{t+j})]$$

$$+ cov(log(Price_t/Rent_t), \rho^J\ log(Price_{t+J}/Rent_{t+J})],$$

where $var(\cdot)$ and $cov(\cdot)$ denote respectively the unconditional variance and unconditional covariance operators. By dividing both sides of approximation (B.3) by $var[log(Price_t/Rent_t)]$, one obtains the following expression in terms of the OLS slope coefficients estimated by regressing future rent growth rates, future rent growth, and future log-price/rent ratios on log-price/rent ratios:

(B.4) $\quad 1 \cong cov[log(Price_t/Rent_t), \sum_{j=1}^{J} \rho^j\ RentGrowth_{t+j}]/var[log(Price_t/Rent_t)]$

$$- cov[log(Price_t/Rent_t), \sum_{j=1}^{J} \rho^j\ NetReturn_{t+j}]/var[log(Price_t/Rent_t)]$$

$$+ cov(log(Price_t/Rent_t), \rho^J\ log(Price_{t+J}/Rent_{t+J})]/var[log(Price_t/Rent_t)].$$

Decomposition (3.2) is the same as expression (B.4) under obvious definitions for $\beta_{Rent}^{(J)}$, $\beta_{Return}^{(J)}$, and $\beta_{P/R}^{(J)}$.

Appendix C

The first equation of motion is the one labeled (EM1) in Table C1.A. The slope coefficients of equation (EM1) are identical to the OLS slopes of regression (OLS1) reported in Table C1.B. The intercept of equation (EM1) is set so as to ensure that the sample estimates of the long-run values for the log-price/rent ratio (2.85), the annual net rate of return (6.3%), and the annual rate of growth in rents (0.4%) are attained as time increases without bound.[18]

For the HL scenario, the second equation of motion is the one labeled (EMHL) in Table C1.A. The slopes of equation EMHL are the respective OLS estimates of regression (OLS2) shown in Table C1.B. As in the case of equation (EM1), the intercept of equation (EMHL) is set to achieve the long-run values.

For the SL scenario, the equation of motion consists of equation (EMSL) in Table C1.A. The intercept of equation (EMSL) is fixed so as to yield the targeted long-run values, and the coefficient for the logarithm of lagged rent growth is obtained by rounding up the first-order autocorrelation coefficient of the net growth in rents over 1900-2002, reported in Table 4. The coefficient for the log-price/rent ratio needs to be negative and sufficiently large in absolute value to ensure properties (SL1) and (SL2) hold. Importantly, the slopes assumed for the second equation of motion in the SL scenario are not consistent with the analog regression estimates shown as regression (OLS3) in Table C1.B. Regression (OLS3) has a poor fit ($R^2 = 0.050$), and none of the slope estimates is different from zero at standard levels of significance.

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[18]Over 1900-2002, rents and prices increased at the average rates of 0.2% and 0.6% per year, respectively (see Table 4). However, since under stationary price/rent ratios, the long-run growth rates for rents and prices must be identical, for the analysis we assumed rents growing at an annual rate of 0.4% (= (0.2% + 0.6%)/2).

Figure 1. Price/rent ratios for farmland, stocks, and housing.
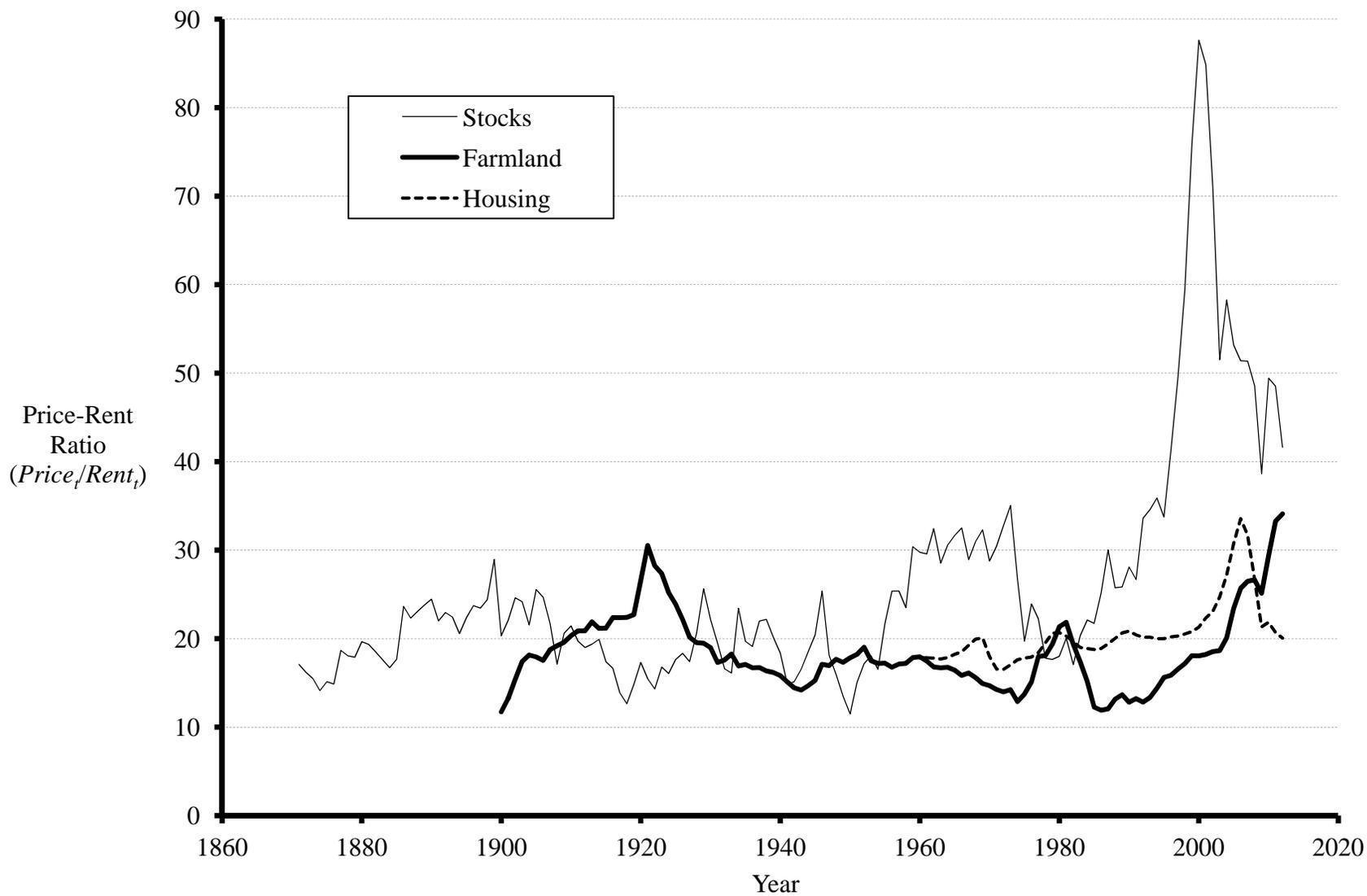
Figure 2. Logarithms of price/rent ratios and weighted sums of subsequent net rates of return for farmland.

Negative of Weighted Sum of Subsequent Net Rates of Return[a]

Logarithm of Price/Rent Ratio [$log(Price_t/Rent_t)$]

Year

——— Negative of Weighted Sum of Subsequent Net Rates of Return (J = 5)
············ Negative of Weighted Sum of Subsequent Net Rates of Return (J = 10)
- - - - - Negative of Weighted Sum of Subsequent Net Rates of Return (J = 15)
–··–··– Negative of Weighted Sum of Subsequent Net Rates of Return (J = 20)
——— Logarithm of Price/Rent Ratio

[a]The weighted sum of subsequent net rates of return is calculated as $\sum_{j=1}^{J} \rho^{j} \ log[(Price_{t+j}+Rent_{t+j})/Price_{t+j-1}]$, for $\rho = 0.9472$.

Figure 3. Relationship between long-run net rate of return and long-run logarithm of price/rent ratio for farmland.
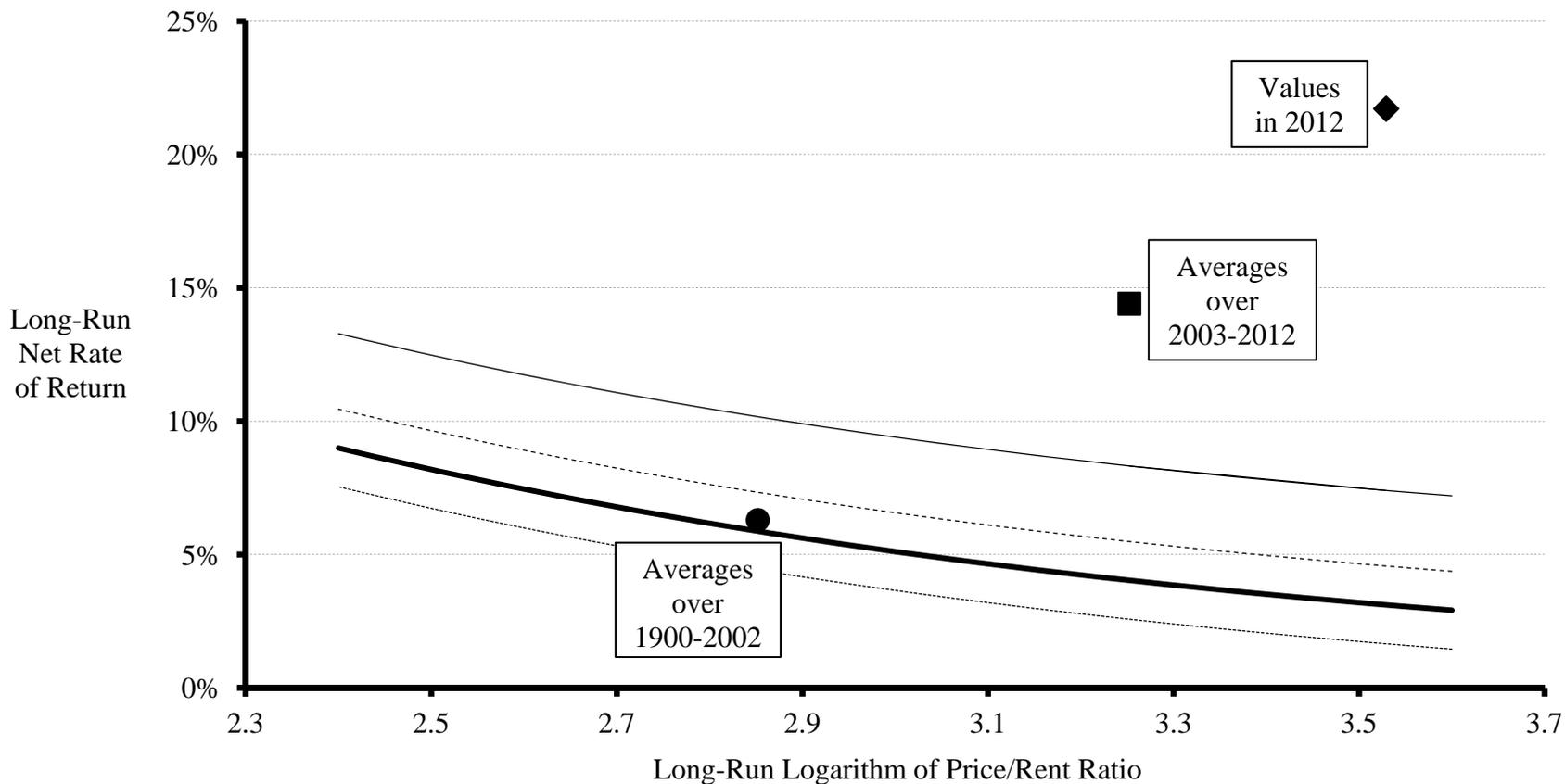
Figure 4. Expected annual net rates of return and annual net rates of price growth under alternative scenarios.
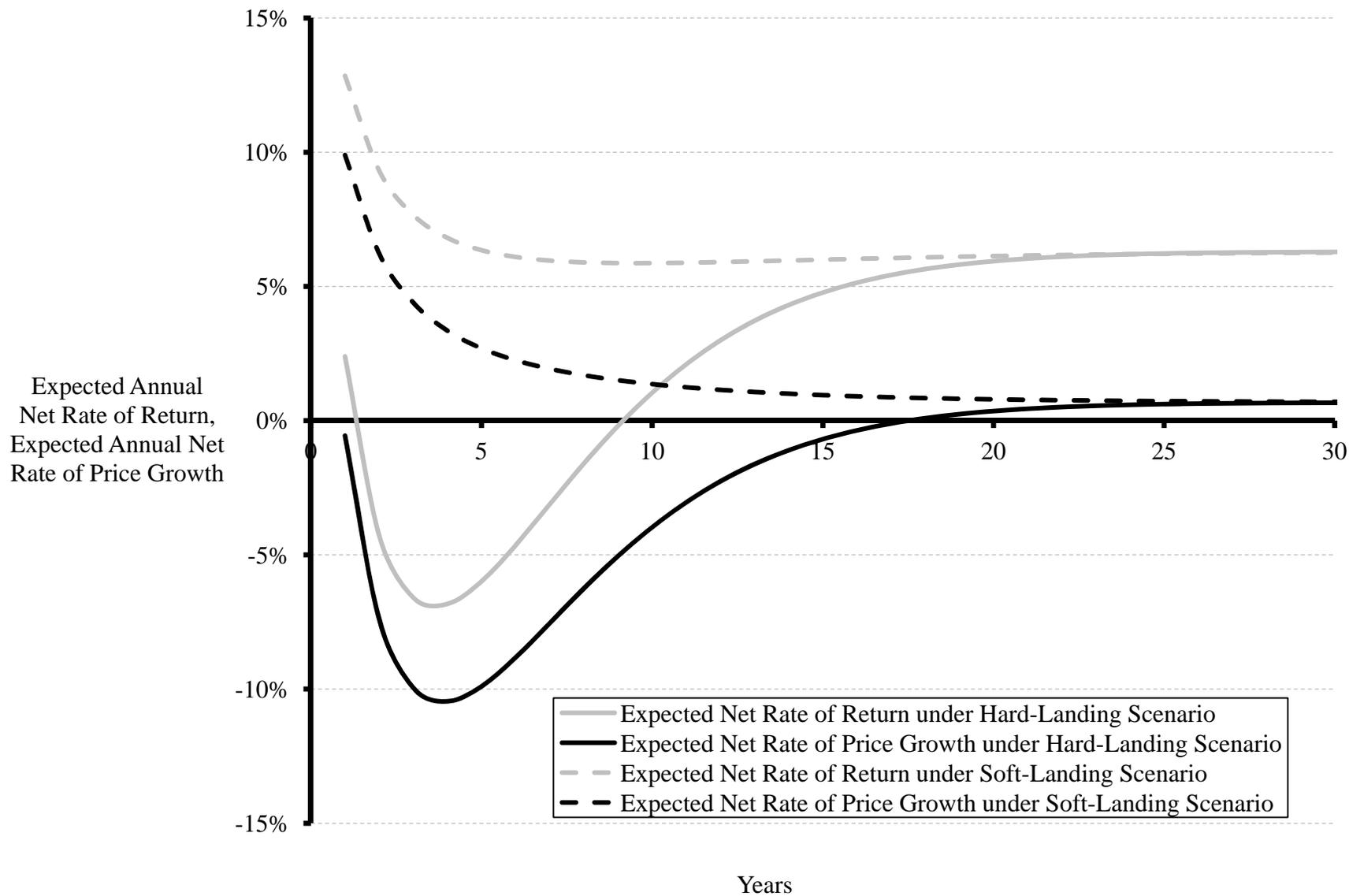
Table 1. Summary Statistics for Relevant Series.

A. Average, Standard Deviations, Minimum, Maximum, First-Order Autocorrelations, and Number of Observations.

Series	Period	Average	Standard Deviation	Minimum	Maximum	First-Order Autocorrelation[b]	Number of Observ.
Price/Rent Ratio for Farmland[a]	1900-2012	18.4	4.4	11.7	34.1	0.987***	113
Price/Rent Ratio for Stocks[a]	1871-2012	26.0	13.4	11.5	87.6	0.948***	142
Price/Rent Ratio for Housing[a]	1960-2012	20.6	3.5	16.5	33.6	0.910***	53
Annual Net Rate of Price Growth for Farmland[a]	1900-2012	0.015	0.097	−0.368	0.257	0.455***	112
Annual Net Rate of Price Growth for Stocks[a]	1871-2012	0.020	0.177	−0.549	0.381	0.031	141
Annual Net Rate of Price Growth for Housing[a]	1960-2012	0.012	0.058	−0.201	0.116	0.615***	52
Annual Net Rate of Rent Growth for Farmland[a]	1900-2012	0.006	0.076	−0.359	0.231	0.205**	112
Annual Net Rate of Rent Growth for Stocks[a]	1871-2012	0.013	0.122	−0.465	0.412	0.123	141
Annual Net Rate of Rent Growth for Housing[a]	1960-2012	0.009	0.017	−0.022	0.051	0.399***	52
Annual Net Rate of Return for Farmland[a]	1900-2012	0.070	0.095	−0.289	0.303	0.446***	112
Annual Net Rate of Return for Stocks[a]	1871-2012	0.064	0.175	−0.491	0.432	0.028	141
Annual Net Rate of Return for Housing[a]	1960-2012	0.060	0.058	−0.156	0.148	0.626***	52

Table 1. Summary Statistics for Relevant Series (Continued).

B. Correlation Coefficients.

	Price/Rent Ratio[a]			Annual Net Rate of Price Growth[a]			Annual Net Rate of Rent Growth[a]			Annual Net Rate of Return[a]		
	Farm.	Stocks	Hous.	Farm.	Stocks	Hous.	Farm.	Stocks	Hous.	Farm.	Stocks	Hous.
Price/Rent Ratio for Farmland[a]	1.00											
Price/Rent Ratio for Stocks[a]	0.10	1.00										
Price/Rent Ratio for Housing[a]	0.52	0.49	1.00									
Annual Net Rate of Price Growth for Farmland[a]	0.21	0.21	0.24	1.00								
Annual Net Rate of Price Growth for Stocks[a]	−0.03	0.13	0.02	0.03	1.00							
Annual Net Rate of Price Growth for Housing[a]	−0.32	0.08	0.08	−0.06	0.30	1.00						
Annual Net Rate of Rent Growth for Farmland[a]	0.06	0.10	0.01	0.74	−0.02	−0.26	1.00					
Annual Net Rate of Rent Growth for Stocks[a]	0.02	0.03	0.24	0.04	0.63	0.50	0.04	1.00				
Annual Net Rate of Rent Growth for Housing[a]	−0.38	−0.18	−0.33	−0.57	0.12	0.20	−0.42	−0.05	1.00			
Annual Net Rate of Return for Farmland[a]	0.10	0.21	0.18	0.99	0.03	−0.03	0.74	0.04	−0.55	1.00		
Annual Net Rate of Return for Stocks[a]	−0.02	0.06	−0.02	0.00	0.99	0.31	−0.03	0.63	0.14	0.01	1.00	
Annual Net Rate of Return for Housing[a]	−0.38	0.02	−0.03	−0.08	0.30	0.99	−0.25	0.48	0.24	−0.05	0.31	1.00

[a]The price/rent ratio is calculated as $Price_t/Rent_t$, where $Price_t$ and $Rent_t$ denote respectively real prices and real rents at time t. The annual net rate of price growth is computed as $log(Price_t/Price_{t-1})$, the annual net rate of rent growth as $log(Rent_t/Rent_{t-1})$, and the annual net rate of return as $log[(Price_t + Rent_t)/Price_{t-1}]$, where $log(\cdot)$ is the natural logarithm. Strictly speaking, these logarithmic variables are approximations because the annual price growth, rent growth, and net rate of return are defined as $(Price_t/Price_{t-1} - 1)$, $(Rent_t/Rent_{t-1} - 1)$, and $[(Price_t + Rent_t)/Price_{t-1} - 1]$, respectively. We report statistics for the logarithmic variables instead because they are used later in the study, and they are very good approximations (note that whenever a number x is very close to zero, $log(x + 1)$ is approximately equal to x).

[b]The first-order autocorrelation for series x_t is the ordinary-least squares estimate of coefficient ϕ_1 in the regression $x_t = \phi_0 + \phi_1 x_{t-1} + error_{x,t}$. Three (two, one) asterisks denote significantly different from zero at the 1% (5%, 10%) level of significance, base on the two-sided t-test.

[c]Correlation coefficients involving series of different lengths are computed using the maximum overlapping period between the series.

Table 2. Unit-Root and Stationarity Tests.

Series	Period	p-Value of Null Hypothesis of	
		Unit Root[b]	Stationarity[c]
Annual Real Rents for Farmland[a]	1900-2012	> 0.10	< 0.01
Annual Real Rents for Stocks[a]	1871-2012	> 0.10	< 0.01
Annual Real Rents for Housing[a]	1960-2012	> 0.10	< 0.01
Annual Gross Rate of Rent Growth for Farmland[a]	1900-2012	< 0.01	> 0.10
Annual Gross Rate of Rent Growth for Stocks[a]	1871-2012	< 0.01	> 0.10
Annual Gross Rate of Rent Growth for Housing[a]	1960-2012	< 0.01	0.06
Price/Rent Ratio for Farmland[a]	1900-2012	> 0.10	> 0.10
Price/Rent Ratio for Stocks[a]	1871-2012	0.06	< 0.01
Price/Rent Ratio for Housing[a]	1960-2012	< 0.01	< 0.01

[a]The annual gross rate of rent growth is computed as $Rent_t/Rent_{t-1}$, and the price/rent ratio is calculated as $Price_t/Rent_t$, where $Rent_t$ and $Price_t$ denote respectively real rents and real prices at time t.

[b]The unit-root null hypothesis is tested by means of the test developed by Elliott, Rothenberg, and Stock (1996), assuming no trend and with the number of lags chosen according to the Schwarz criterion.

[c]The null hypothesis of stationarity is tested by performing the test proposed by Kwiatkowski *et al.* (1992), assuming no trend and using the optimal bandwidth selected according to Newey and West (1994), and a quadratic spectral kernel.

Table 3. Decompositions of Historical Price/Rent Ratios.

Series	Horizon	Ordinary Least Squares Coefficients[a]			Coefficients Implied by Vector Auto-Regressions[b]		
	(J)	$\beta_{Rent,\text{OLS}}^{(J)}$	$\beta_{Return,\text{OLS}}^{(J)}$	$\beta_{P/R,\text{OLS}}^{(J)}$	$\beta_{Rent,\text{VAR}}^{(J)}$	$\beta_{Return,\text{VAR}}^{(J)}$	$\beta_{P/R,\text{VAR}}^{(J)}$
Farmland	1	0.02	0.04	0.93	0.02	0.05	0.92
	5	−0.11	0.62	0.49	0.02	0.44	0.52
	10	−0.32	1.22	0.10	−0.00	0.77	0.22
	15	−0.34	1.39	−0.06	−0.02	0.91	0.09
	20	−0.34	1.47	−0.13	−0.02	0.97	0.04
	25				−0.02	0.99	0.01
	∞				−0.03	1.01	0.00
Stocks	1	0.02	0.07	0.90	0.02	0.07	0.90
	5	0.05	0.31	0.62	0.09	0.28	0.60
	10	0.01	0.56	0.38	0.15	0.45	0.36
	15	−0.08	0.85	0.18	0.18	0.55	0.21
	20	−0.12	1.10	0.01	0.20	0.62	0.13
	25				0.22	0.65	0.08
	∞				0.23	0.70	0.00
Housing	1	−0.03	0.15	0.88	−0.02	0.12	0.90
	5	−0.12	0.84	0.27	−0.09	0.85	0.23
	10	−0.25	0.62	0.60	−0.09	1.13	−0.06
	15	−0.44	0.86	0.56	−0.08	1.08	−0.02
	20	−0.34	1.12	0.21	−0.08	1.07	0.00
	25				−0.08	1.07	0.00
	∞				−0.08	1.07	0.00

[a] $\beta_{Rent,\text{OLS}}^{(J)}$ and $\beta_{P/R,\text{OLS}}^{(J)}$ are the ordinary least squares (OLS) slope coefficients estimated by regressing $\Sigma_{j=1}^{J}\rho^{j}$ $Log(Rent_{t+j}/Rent_{t+j-1})$ and $\rho^{J} Log(Price_{t+J}/Rent_{t+J})$, respectively, on $Log(Price_t/Rent_t)$. $\beta_{P/R,\text{OLS}}^{(J)}$ is the negative of the OLS slope coefficient calculated by regressing $\Sigma_{j=1}^{J}\rho^{j} Log[(Price_{t+j}+Rent_{t+j})/Price_{t+j-1}]$ on $Log(Price_t/Rent_t)$. Constant ρ is set equal to $\rho = 0.9472$ for farmland, $\rho = 0.9595$ for stocks, and $\rho = 0.9531$ for housing.

[b] $\beta_{Rent,\text{VAR}}^{(J)}$, $\beta_{Return,\text{VAR}}^{(J)}$, and $\beta_{P/R,\text{VAR}}^{(J)}$ are defined as follows. Let $\underline{1}_{3\times3}$ denote the (3×3) identity matrix, $y_t \equiv Log(Price_t/Rent_t)$, $r_t \equiv Log[(Price_t+Rent_t)/Price_{t-1}]$, $g_t \equiv Log(Rent_t/Rent_{t-1})$, $\underline{X}_t \equiv [y_t\ r_t\ g_t]$, and $\underline{B} \equiv [\underline{\beta}_y;\ \underline{\beta}_r;\ \underline{\beta}_g]$, where $\underline{\beta}_y \equiv [\beta_{yy}\ \beta_{yr}\ \beta_{yg}]$, $\underline{\beta}_r \equiv [\beta_{ry}\ \beta_{rr}\ \beta_{rg}]$, and $\underline{\beta}_g \equiv [\beta_{gy}\ \beta_{gr}\ \beta_{gg}]$ are vectors comprising the OLS slope coefficients estimated by regressing y_{t+1}, r_{t+1}, and g_{t+1}, respectively, on $\underline{X}_t$. Then, $\beta_{Return,\text{VAR}}^{(J)}$ and $\beta_{Rent,\text{VAR}}^{(J)}$ are elements (2, 1) and (3, 1), respectively, of the matrix $\underline{B}[\underline{1}_{3\times3} - \rho^{J} \underline{B}^{J}] [\underline{1}_{3\times3} - \rho^{J} \underline{B}^{J}]^{-1}$, and $\beta_{P/R,\text{VAR}}^{(J)}$ is the (1, 1) element of the matrix $\rho^{J} \underline{B}^{J}$. Constant ρ is set equal to $\rho = 0.9472$ for farmland, $\rho = 0.9595$ for stocks, and $\rho = 0.9531$ for housing.

Table 4. Summary Statistics for Relevant Farmland Series Over Selected Sub-Samples.

Series	Period	Average	Standard Deviation	Minimum	Maximum	First-Order Autocorrelation[b]	Number of Observ.
Price/Rent Ratio[a]	1900-2002	17.6	3.5	11.7	30.5	0.949***	103
Price/Rent Ratio[a]	2003-2012	26.3	5.0	18.6	34.1	0.927***	10
Price/Rent Ratio[a]	1916-1925[c]	25.2	2.9	22.4	30.5	0.680***	10
Annual Net Rate of Price Growth[a]	1900-2002	0.006	0.094	−0.368	0.257	0.426***	102
Annual Net Rate of Price Growth[a]	2003-2012	0.106	0.080	−0.052	0.207	−0.032	10
Annual Net Rate of Price Growth[a]	1972-1981[d]	0.080	0.091	−0.031	0.249	0.252	10
Annual Net Rate of Rent Growth[a]	1900-2002	0.002	0.075	−0.359	0.231	0.182***	102
Annual Net Rate of Rent Growth[a]	2003-2012	0.045	0.070	−0.020	0.164	0.284	10
Annual Net Rate of Rent Growth[a]	1966-1975[e]	0.057	0.070	−0.013	0.231	0.029	10
Annual Net Rate of Return[a]	1900-2002	0.063	0.075	−0.289	0.303	0.436***	102
Annual Net Rate of Return[a]	2003-2012	0.144	0.075	−0.014	0.237	−0.087	10
Annual Net Rate of Return[a]	1972-1981[d]	0.140	0.095	0.023	0.303	0.312	10
Natural Logarithm of Price/Rent Ratio[a]	1900-2002	2.85	0.19	2.46	3.41	0.953***	103
Natural Logarithm of Price/Rent Ratio[a]	2003-2012	3.25	0.19	2.93	3.53	0.929***	10
Natural Logarithm of Price/Rent Ratio[a]	1916-1925[c]	3.22	0.11	3.11	3.42	0.699***	10

[a]The price/rent ratio is calculated as $Price_t/Rent_t$, where $Price_t$ and $Rent_t$ denote respectively real prices and real rents at time t. The annual net rate of price growth is computed as $log(Price_t/Price_{t-1})$, the annual net rate of rent growth as $log(Rent_t/Rent_{t-1})$, the annual net rate of return as $log[(Price_t + Rent_t)/Price_{t-1}]$, and the natural logarithm of the price/rent ratio as $log(Price_t/Rent_t)$, where $log(\cdot)$ is the natural logarithm. Strictly speaking, the annual price growth, rent growth, and net rate of return are defined as $(Price_t/Price_{t-1} - 1)$, $(Rent_t/Rent_{t-1} - 1)$, and $[(Price_t + Rent_t)/Price_{t-1} - 1]$, respectively. We report statistics for the logarithmic variables instead, because they are used in other sections of the study, and they are very good approximations (note that whenever a number x is very close to zero, $log(x + 1)$ is approximately equal to x).

[b]The first-order autocorrelation for series x_t is the ordinary-least squares estimate of coefficient ϕ_1 in the regression $x_t = \phi_0 + \phi_1 x_{t-1} + error_{x,t}$. Three (two, one) asterisks denote significantly different from zero at the 1% (5%, 10%) level of significance, base on the two-sided t-test.

[c]1916-1925 was the ten-year period with the second-largest average price/rent ratio in the sample.

[d]1972-1981 was the ten-year period with the second-largest average net rate of price growth and average net rate of return in the sample.

[e]1966-1975 was the only occurrence of two consecutive five-year periods with an average net rate of rent growth greater than the average net rate of rent growth registered between 2003 and 2012.

Table C1. Equations of Motion and Ordinary Least-Squares (OLS) Regressions for Farmland Series.

A. Equations of Motion for Farmland Series.

Equation of Motion[a]

(EM1) $\quad log\left(\dfrac{Price_{t+1}}{Rent_{t+1}}\right) = 0.123 + 0.947\ log\left(\dfrac{Price_t}{Rent_t}\right) + 0.490\ log(Return_t) - 0.383\ log\left(\dfrac{Rent_t}{Rent_{t-1}}\right)$

(EMHL) $\quad log(Return_{t+1}) = 0.372 - 0.121\ log\left(\dfrac{Price_t}{Rent_t}\right) + 0.602^{***}\ log(Return_t) - 0.316\ log\left(\dfrac{Rent_t}{Rent_{t-1}}\right)$

(EMSL) $\quad log\left(\dfrac{Rent_{t+1}}{Rent_t}\right) = -0.337 + 0.12\ log\left(\dfrac{Price_t}{Rent_t}\right) + 0.2\ log\left(\dfrac{Rent_t}{Rent_{t-1}}\right)$

B. OLS Regressions for Farmland Series, estimated over 1900-2002 period.

OLS Regression[a,b]	No. Observ.	R^2

(OLS1) $\quad log\left(\dfrac{Price_{t+1}}{Rent_{t+1}}\right) = \underset{(0.082)}{0.124} + \underset{(0.028)}{0.947^{***}}\ log\left(\dfrac{Price_t}{Rent_t}\right) + \underset{(0.085)}{0.490^{***}}\ log(Return_t) - \underset{(0.11)}{0.383^{***}}\ log\left(\dfrac{Rent_t}{Rent_{t-1}}\right)$ 　　101　　0.920

(OLS2) $\quad log(Return_{t+1}) = \underset{(0.13)}{0.370^{***}} - \underset{(0.044)}{0.121^{***}}\ log\left(\dfrac{Price_t}{Rent_t}\right) + \underset{(0.13)}{0.602^{***}}\ log(Return_t) - \underset{(0.16)}{0.316^{*}}\ log\left(\dfrac{Rent_t}{Rent_{t-1}}\right)$ 　　101　　0.277

(OLS3) $\quad log\left(\dfrac{Rent_{t+1}}{Rent_t}\right) = \underset{(0.12)}{0.044} - \underset{(0.040)}{0.018}\ log\left(\dfrac{Price_t}{Rent_t}\right) + \underset{(0.12)}{0.140}\ log(Return_t) + \underset{(0.15)}{0.048}\ log\left(\dfrac{Rent_t}{Rent_{t-1}}\right)$ 　　101　　0.050

[a] $log(\cdot)$ is the natural logarithm, $Price_t$ and $Rent_t$ denote respectively real prices and real rents at time t, and $Return_t = (Price_t + Rent_t)/Price_{t-1}$.
[b] t statistics are shown in parenthesis below the corresponding OLS coefficients.
*** (**, *) Denotes significance at the 1% (5%, 10%) level, based on the two-sided t statistic.