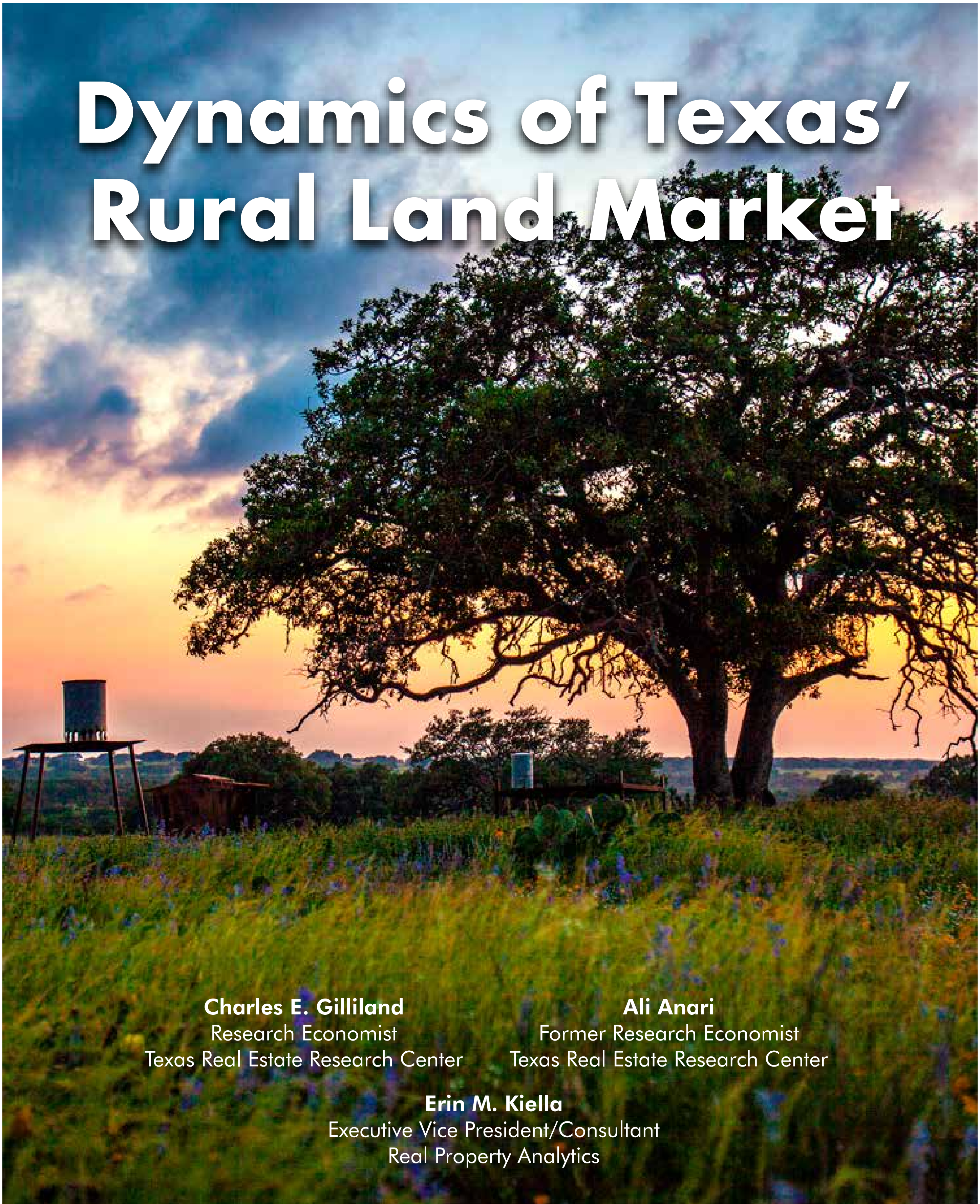

Dynamics of Texas' Rural Land Market

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Abstract

A multivariate model of Texas rural land markets reveals that Texas' total personal income, the Federal Reserve funds rate (fed funds rate), and oil prices drive land market developments. These dynamics conform to general investment markets in contrast with conventional paradigms of the illiquid and inflation-hedging qualities of rural land markets. The model demonstrates general macroeconomic factors drive Texas rural land market trends, not the usual agricultural financial drivers examined in most research. Knowledge that rural land markets are decoupled from traditional agricultural influences should inspire state and local policymakers to rethink conventional assumptions about measures targeting rural land markets.

Keywords: forecast error decomposition, forecast simulation, impulse response functions, land price, land sales, Texas rural land model, vector autoregression.

JEL codes: R11, R12, R13, R14

Dynamics of Texas' Rural Land Market

A model of Texas' rural land markets reveals dynamics similar to those observed in general investment markets. These results contrast with the conventional paradigm focused on the illiquid and inflation-hedging qualities of rural land markets. The model demonstrates general macroeconomic factors drive Texas' rural land market trends, not the usual rural or agricultural financial drivers examined in most research.

This aggregate, multivariate econometric model describes land prices and sales volume not as a function of net farm income but as a function of Texas' total personal income, the fed funds rate, and oil prices. Of those market influences, oil prices contribute the most uncertainty. Knowledge that rural land markets are decoupled from traditional agricultural influences should inspire state and local policymakers to rethink conventional assumptions about the effectiveness of measures targeting rural land markets and landowners.

This research strives to (1) explain the aggregate dynamics of Texas land markets, (2) identify the most important economic indicators of land market dynamics, (3) analyze the impacts of U.S. macroeconomic and monetary policies on these market drivers, and (4) analyze the land market business cycle.

Section 1 reviews land market modeling literature. Section 2 introduces the Texas rural land market model. Section 3 presents empirical results. Section 4 presents the results of simulations using the estimated model to forecast impacts of changes in U.S. monetary policy rates on the state's rural land market. Section 5 concludes with a summary of the findings.

Land Market Modeling Literature

Many analysts have provided insights into land markets focusing primarily on prices related to either microeconomic or macroeconomic exogenous drivers of markets. For example, Alston (1986) focused on macroeconomic factors to try to explain dramatic changes in cropland prices. Specifically, he focused on the relationship between inflation and cropland prices. Buyers, he hypothesized, considered hedging opportunities against inflation by investing in cropland. Using a tightly parameterized empirical model, he concluded there is no support for the notion of cropland as a hedge for inflation and that net rental income was the primary driver for most of the real growth in U.S. land prices during the 20 years prior to 1982.

Richard E. Just and John A. Miranowski attempted to explain changes in cropland prices using previous literature's determinants. The authors identify the relative roles of each models' influence using mainly a theoretical framework with some empirical analysis. They consider farm and nonfarm returns, inflation, credit, the real interest rate on farm real estate debt, government payments, taxation, and more. Their results indicate inflation, net returns, and the discount rate are the largest contributors. Using these results, Just and Miranowski found they could successfully predict land prices using current and lagged rental rates, with lags of up to eight years. They note that while lagging rent by those amounts proves effective, it lacks substance in terms of "defensible economic rationale." Allen M. Featherstone and Timothy G. Baker and, in a separate study, Barry Falk agree that these techniques, while proving strong in terms of an r-squared, are not applicable.

Gregory Ibendahl and Terry Griffin provide intuition on why the lags are important in determining the land price. They explain how an asymmetric relationship exists between changes in rent and land prices. The asymmetries are created when the lessee chooses to share varying amounts of information during productive and non-productive years. The authors determine this asymmetric relationship between lessee and landowner is the basis for the need to use lags in determining land prices.

Emanuel Melichar originated the use of cash rent as a proxy for income, placing emphasis on expected changes in rental rates. His work arose from the rapid increases in farm asset prices. He noted the importance of understanding where the capital gains are occurring—from the return to the asset or other influences. He states the increases in returns to land over labor are the primary cause of the increases in land prices. “Over the last 25 years, the proportion of the total return that could be ascribed to operators’ labor has dropped from 63 percent to 17 percent, while the proportion that could be regarded as a return to production assets has risen from 25 percent to 69 percent,” he wrote.

To properly assess the income to land price relationship, Melichar states net farm income cannot be reliably used for several reasons. First, net farm income is an aggregate measure, whereas land prices are a unit price. Using net farm income to represent return to land alone ignores the number of other productive assets that are included in the net farm income measure. Additionally, net farm income lacks comprehension of the non-operator landowner. When considering the substantial portion of land owned by non-operators, income from rent and interest payments on debt should be included in income while operator’s dwellings should be excluded.

Lindon J. Robison, David A. Lins, and Ravi Venkataraman try to improve on the capitalized valuation model by including the expectations of changes in factors. The growth rate in cash returns to land, inflation expectations, income, and capital gains taxes are included in their model. They determine that inflation and non-agricultural demand are important influencers. Similarly, Charles B. Moss considers the effects of returns, interest rates, and inflation on cropland values, concluding inflation is the biggest driver of land values.

Andrew Schmitz takes a closer look at the involvement of government policy and its effect on value with a focus specifically on boom-and-bust cycles. He finds that cropland values and inflation are positively related. He states these results show inflation was a significant contributor to the rise in cropland prices in the 1970s and 1980s.

However, these analyses approach the land value question with farmers as the sole end users of the land. This approach may adequately characterize cropland in remote locations; however, as Ian W. Hardie, Tulika A. Narayan, and Bruce L. Gardner noted, other sources of demand can impact land prices. Specifically, land prices in the mid-Atlantic area were more closely linked to house prices in Baltimore than net farm income. Allison Borchers, Jennifer Ifft, and Todd Kuethe explored the role of use values and amenities in setting prices, concluding farmland values are "only partially explained by agricultural returns." Other current and potential future uses substantially impacted land price trends, meaning non-agricultural influences are likely important influences on values.

Research published by Wendong Zhang and C.J. Nickerson studies land values in relation to distance to urban centers and housing market prices. They found that the 2008-09 housing bust negatively impacted farmland prices as demand from urban-based potential users of land temporarily evaporated. These results suggest the market for land presides over a contest between agriculturally and non-agriculturally based buyers.

These latest studies recognize the complex nature of land markets where multiple potential uses compete for space. The market ebbs and flows with the fortunes of potential users. This means levels of personal income influence demand from all sectors of the economy by expanding available funds for land purchases. Oil prices play an important role in Texas by providing extra income to current landowners. This study focuses on the land market as a complex of interrelated relationships driving the demand for and supply of land as they interact to set prices paid and quantities exchanged in Texas rural land markets.

Texas Rural Land Market Model

The Texas rural land database includes all reported sales not involved in urban-style developments, greater than regional minimum acreages ranging from 45 to 160 acres, and with prices less than $30,000 per acre. These criteria, along with location and current use, identify the sales as rural in character, so they exclude transitional or development tracts. Frequently observed uses consist of recreation, farming, ranching, natural resource extraction, and timber production. This market data constitute a quarterly time series of both quantities and prices of rural land sold starting in first quarter 1966. The Texas land market dataset reflects an analysis of information reported by a network of corresponding market observers to the Texas Real Estate Research Center (TRERC) at Texas A&M University.

The reports provide quarterly annualized price and acreage statistics for individual transactions across Texas. The published data present prices based on the studied transactions. Market statistics report prices adjusted for variations in size distribution for each of seven regional markets across the periods studied. The resulting time series for Texas consists of a weighted average of regional prices and total acres traded.

The reported transactions include a mixture of land uses—farming, ranching, wildlife management, minerals, etc. Therefore, statistics in the datasets reflect overall market conditions without regard to a specific land use. For a detailed discussion of the data, see "Using the Center's Rural Land Market Data" on TRERC's website.

Applying Granger causality tests to land price and land sale volume variables and a selection of economic indicators showed that, in addition to their own dynamics, total personal income in Texas, crude oil prices, and fed funds rate drive aggregate land market prices and quantities traded. Using these time series data, TRERC estimated a multivariate econometric model of the state's rural land market.

The model consists of five equations representing the demand for and supply of land. The endogenous variables (prices and quantities of land sold) depend on the exogenously determined fed fund rates, Texas aggregate incomes, and oil prices. After testing several models using these variables both adjusted and unadjusted for inflation, TRERC found nominal values generate the most plausible results. This suggests agents in this market make buying and selling decisions based on nominal dollars, rather than real, inflation-adjusted dollars. That means money illusion exists in this market.[1] Study results also show land price stickiness plus long memory impulse response functions for land prices, supporting the suspected presence of money illusion, according to E. Shafir, P. Diamond, and A. Tversky. Consequently, the selected final model relied on nominal values of land prices, incomes, and oil prices.

The structure of the equations resulted from testing several lag orders to empirically determine the most statistically significant structure. The selected model is a near-VAR (vector autoregression) model of the Texas land market, represented as:

(1.1) $Sales_t = \alpha_0 + \alpha_1 Sales_{t-1} + \alpha_2 Sales_{t-2} + \alpha_3 Price_{t-2} + \alpha_4 Pin_t + \alpha_5 FedF_{t-4}$

(1.2) $Price_t = \beta_0 + \beta_1 Price_{t-1} + \beta_2 Price_{t-2} + \beta_3 Sales_{t-2} + \beta_4 Oilp_t + \beta_5 FedF_{t-4}$

(1.3) $FedF_t = \theta_0 + \theta_1 FedF_{t-1} + \theta_2(\dot{gdpus}_t - gdpus^T) + \theta_3(\dot{infrus}_t - infrus^T)$

(1.4) $Pin_t = \lambda_0 + \lambda_1 Pin_{t-1} + \lambda_2 Pin_{t-2} + \lambda_3 Oilp_t + \lambda_4 FedF_{t-4}$

(1.5) $Oilp_t = \phi_0 + \phi_1 Oilp_{t-1} + \phi_2 Oilp_{t-2}$

where $Sales$ = quantity of land sold, $Price$ = average land price, Pin = total Texas personal income, $Oilp$ = oil price, all in natural logarithms, and $Fedf$ = fed funds rate, $\dot{gdpus}$ = U.S.

[1] Money illusion according to Fisher (1928) is widespread as many people think in nominal rather than real terms. See also Shafir, Diamond, and Tversky, A. (1997).

gross domestic product (GDP) growth rate, $\dot{infrus}$ = U.S. GDP inflation rate, in percentages, and $gdpus^T$ and $infrus^T$ are the central bank targets for $gdpus$ and $\dot{infrus}$, respectively.

Equations (1.1) and (1.2) comprise the structural model representing the demand and supply sides of the state's rural land market. According to demand theory, equation (1.1) represents demand when the land price coefficient is negative ($\alpha_3 < 0$) and the income coefficient is positive ($\alpha_4 > 0$).

Equation (1.2) represents the supply side when the coefficient of land quantity is positive. According to VAR approach, the demand and supply sides of the land model are identified if impulse response functions show a positive (negative) land sales response to land price shocks and a negative (positive) land price response to land sales shocks. The income variable Pin does not appear in the equation (1.2). Instead, equation (1.2) includes oil price as an explanatory variable. Oil price does not appear in equation (1.1). According to the Cowles Commission[2] approach for identification, equations (1.1) and (1.2) are identified as demand and supply sides of the land market.[3]

Both equations (1.1) and (1.2) include the fed funds rate to investigate the impacts of changes in U.S. monetary policy rate on land prices and land quantities. TRERC expects the fed funds rate to have negative impacts on land price and quantity represented by $\alpha_5 < 0$, and $\beta_5 < 0$. TRERC uses the fed funds rate to represent both the current stance of monetary policy as well as the availability and cost of credit.

The impacts of Texas aggregate income, oil price, and the fed funds rate on land prices and land sales correspond to their coefficients in land sales equation (1.1) and land price equation (1.2)

[2] The website of the Cowles Foundation for Research in Economics is cowles.yale.edu.
[3] For a discussion of the traditional Cowles Commission and VAR approaches to the identification problem, see Sims (1980), Sims (1982), Malinvaud (1983), and Qin (2011).

(i.e., α_4, α_5, β_4, and β_5). To investigate the impacts of the unexpected changes in income, oil price, and fed funds rate on the dynamics of the state's land markets, TRERC specified equations (1.3), (1.4), and (1.5) and included them in the system of equations. Unexpected changes, also called shocks, surprises, or innovations, are residuals of the equations in the system.

Equation (1.3) is a monetary authority reaction function in the form of a dynamic Taylor rule where fed funds rate changes in response to deviations of U.S. GDP growth rates and U.S. GDP inflation rates from their central bank targets. Variables θ_2 and θ_3, the relative weights of the inflation rate and output gap in the Taylor rule equation, were estimated empirically.[4] In equation (1.4), Texas personal income depends on its own dynamics, oil prices, and the fed funds rate. Given that prices of West Texas Intermediate (WTI) crude oil used in the model derive from international oil market fluctuations influenced by OPEC, equation (1.5) assumes that exogenously driven oil prices result from two lags of oil prices.

Solving the model by setting $x_t = x_{t-1}$ for all variables in the model results in the steady state solution of the dynamic land model presented in Table 1. In the steady state, endogenous variables are expressed in terms of exogenous variables, and the coefficients of exogenous variables are long-run elasticities of endogenous variables with respect to exogenous variables.

[4] As Bernanke (2003) has observed "… constrained discretion characterizes the current monetary policy framework of the United States . . ." However, various versions of the Taylor rule have been used widely to describe the Fed's reaction function in the monetary policy research literature. See Asso, Kahn, and Leeson (2010) and Yellen (2017). For discussions of rules versus discretion in monetary policy, see Simons (1936), Friedman, (1960), Kydland and Prescott (1977), Barro and Gordon (1983), Fischer (1988), and Taylor (1993), among others.

Table 1. Steady State Solution of the Dynamic Land Model

	Endogenous Variables	
	$Sales_t$	$Price_t$
Intercept Exogenous Variables	$\frac{\alpha_0(1-\beta_1-\beta_2)+\alpha_3\beta_0}{(1-\alpha_1-\alpha_2)(1-\beta_1-\beta_2)-\alpha_3\beta_3}$	$\frac{\beta_0(1-\alpha_1-\alpha_2)+\alpha_0\beta_3}{(1-\alpha_1-\alpha_2)(1-\beta_1-\beta_2)-\alpha_3\beta_3}$
Pin_t	$\frac{\alpha_4(1-\beta_1-\beta_2)}{(1-\alpha_1-\alpha_2)(1-\beta_1-\beta_2)-\alpha_3\beta_3}$	$\frac{\alpha_4\beta_3}{(1-\alpha_1-\alpha_2)(1-\beta_1-\beta_2)-\alpha_3\beta_3}$
$Oilp_t$	$\frac{\alpha_3*\beta_4}{(1-\alpha_1-\alpha_2)(1-\beta_1-\beta_2)-\alpha_3\beta_3}$	$\frac{\beta_4(1-\alpha_1-\alpha_2)}{(1-\alpha_1-\alpha_2)(1-\beta_1-\beta_2)-\alpha_3\beta_3}$
$FedF_t$	$\frac{\alpha_5(1-\beta_1-\beta_2)+\alpha_3\beta_5}{(1-\alpha_1-\alpha_2)(1-\beta_1-\beta_2)-\alpha_3\beta_3}$	$\frac{\beta_5(1-\alpha_1-\alpha_2)+\alpha_5\beta_3}{(1-\alpha_1-\alpha_2)(1-\beta_1-\beta_2)-\alpha_3\beta_3}$

Source: Texas Real Estate Research Center's Texas Rural Land Econometric Model

A Cholesky decomposition of the covariance matrix generates orthogonalized impulse response functions and forecast error variance decompositions, facilitating an understanding of the impacts of shocks from changes in the fed funds rate, Texas aggregate income, and oil prices on land prices and land sales. The results from the Cholesky decomposition may depend crucially on the ordering of the variables in the system. TRERC used the order $FedF$, $Oilp$, Pin, $Price$, $Sales$. The ordering ensures $FedF$, $Oilp$, and Pin have impacts on $Price$ and $Sales$, but land price and sales have no impact on $FedF$, $Oilp$, and Pin.

Empirical Results

In addition to the TRERC land market data, we obtained exogenous time series data sets from the Federal Reserve Economic Data (FRED) database on the St. Louis Fed website[5] or the Haver Analytics Database.[5] Those series included Texas total personal income, WTI crude oil prices, fed funds rate, U.S. GDP growth rates, and U.S. GDP inflation rates. The quarterly sample runs from fourth quarter 1967 to fourth quarter 2019. Table 2 provides descriptive statistics for the time series

[5] The St. Louis Fed website is https://fred.stlouisfed.org/.

variables used in the model. Time series of U.S. GDP growth rates and GDP inflation rates were also four-quarter moving averages.

Table 2. Descriptive Statistics for Variables in the Model, 4Q1967-4Q2019

Variables	Mean	Media	Maximum	Minimum	Standard Deviation
Land price, \$, $Price$	964.02	636.75	2,972.33	151.32	764.33
Land sales,1,000 acres, $Sales$	419.64	383.62	763.85	228.50	119.27
Texas total income, \$billion, Pin	507.13	355.12	1,541.18	295.89	436.12
Oil price, \$ per barrel, $Oilp$	33.95	24.6	123.96	2.97	27.95
Fed funds rate, %, $FedF$	5.21	5.25	17.78	0.07	3.81
U.S. annual GDP growth rate, %, $gd\dot{p}us$	2.84	2.93	8.58	-3.88	2.11
U.S. annual GDP inflation rate, %, $in\dot{f}rus$	3.51	2.68	11.05	0.28	2.33

Source: Texas Real Estate Research Center's Texas Rural Land Econometric Model

Logarithmic transformations of four-quarter moving averages of land prices and land sales generated the most plausible as well as the most statistically significant results.

Table 3 shows the estimated dynamic near-VAR model of the Texas rural land market using A. Zellner's seemingly unrelated regression equations method and Eviews11 econometric software. Lag orders for the variables in the model were determined empirically to generate the largest t-values for the estimated coefficients. Lag orders for the fed funds rate generated the largest t-values when a lag order of four quarters is specified, consistent with M. Friedman's 1961 study of the lagged impact of monetary policy. All estimated coefficients in the land sales equation are statistically significant at least the 5 percent level. The negative coefficient of price and positive coefficient of income in the land sales equation shows the equation represents the demand side of the Texas rural land market.

Table 3. Estimated Texas Rural Land Model, Using Q41967-Q42019 Data

$$Sales_t = 0.702 + 1.246QSales_{t-1} - 0.333Sales_{t-2} - 0.045Price_{t-2} + 0.024Pin_t - 0.379*FedF_{t-4}$$

$(4.96)^{**}$ $(19.79)^{**}$ $(5.43)^{**}$ $(2.67)^{**}$ $(2.00)^{*}$ $(2.53)^{*}$ R^2=0.94, DW=2.09

$$Price_t = -0.014 + 1.633Price_{t-1} - 0.642Price_{t-2} + 0.011Sales_{t-2} + 0.005Oilp_t - 0.072*FedF_{t-4}$$

(0.44) $(30.55)^{**}$ $(12.18)^{**}$ $(2.46)^{*}$ $(1.86)^{+}$ $(2.14)^{*}$ R^2=0.99, DW=2.38

$$FedF_t = 0.005 + 0.908Fed_{t-1} + 0.174\,(\dot{gdpus}_t - gdpus^T) + 0.139\,(\dot{infrus}_t - infrus^T)$$

$(4.09)^{**}$ $(40.35)^{**}$ $(6.27)^{**}$ $(3.76)^{**}$ R^2=0.95, DW=1.69

$$Pin_t = 0.054 + 1.258Pin_{t-1} - 0.269Pin_{t-2} + 0.007Oilp_t - 0.050*FedF_{t-4}$$

$(6.95)^{**}$ $(19.62)^{**}$ $(4.25)^{**}$ $(3.87)^{**}$ $(1.98)^{*}$ R^2=0.99, DW=2.02

$$Oilp_t = 0.077 + 1.115Oilp_{t-1} - 0.136Oilp_{t-2}$$

$(2.34)^{*}$ $(16.53)^{**}$ $(2.03)^{*}$ R^2=0.98, DW=1.91

Notes: $Sales_t$= quantity of land sold, $Price_t$= average land price, Pin_t = total Texas personal income, $Oilp_t$ = oil price, all in natural logarithms, and $FedF_t$= fed funds rate, $\dot{gdpus}_t$ = U.S. GDP growth rate, $\dot{infrus}$= U.S. GDP inflation rate, in percentages, and $gdpus^T$ and $infrus^T$ are the central bank targets representing $\dot{gdpus}_t$ and $\dot{infrus}$ respectively. **, *, and $^{+}$ denote statistical significance at the 1 percent, 5 percent, and 10 percent respectively. *DW* = Durbin-Watson statistics.

Source: Texas Real Estate Research Center's Texas Rural Land Econometric Model

The positive estimated coefficient of land quantity in the land price equation, significant at the 5 percent level, shows the equation represents the supply side of the land market. The coefficient for oil price in the land price equation is positive and significant at the 10 percent level.

These results suggest demand and supply for land in these markets conform to the identification in the Cowles Commission approach. The negative coefficients for the fed funds rate in both land price and land sales equations and in the Texas income equation confirm the negative impact of monetary policy rates on land prices, land sales, and Texas incomes. These coefficients help explain why land sales doubled from 383,600 acres in second quarter 2002 to 763,850 acres in fourth quarter 2005 as the fed funds rate fell from 6.47 percent in fourth quarter 2000 to 1 percent in first quarter 2004. To help the U.S. economy recover from a 2001 recession caused by the bursting of the dot.com bubble, the Fed actively reduced rates. Fearing higher inflation, the Fed then reversed course and raised the fed funds rate from 1 percent in first quarter 2004 to 5.26 percent in first quarter 2007. This increase, combined with a decline in personal income, ensured

Texas rural land sales, like the rest of the U.S. economy, fell in the recession. Sales fell by 69.7 percent from 763,850 acres in fourth quarter 2005 to a historically low 231,360 acres in second quarter 2010.

The estimated central bank reaction function assumes a target GDP inflation rate of 2.8 percent and target U.S. GDP growth rate of 3.5 percent in real terms, their historical averages over the sample period. The positive coefficients of deviations from targets suggest the Fed should increase (decrease) the fed funds rate when GDP growth rates in real terms and GDP inflation rates are above (below) their targets.

The coefficients of exogenous variables (income, oil price, fed funds rate) in the sales and price equations in Table 3 are short-run elasticities of endogenous variables with respect to exogenous variables. Table 4 presents long-term elasticities of endogenous variables with respect to exogenous variables using the relationships in Table 1.

Table 4. Long-Term Elasticities of Endogenous Variables with Respect to Exogenous Variables

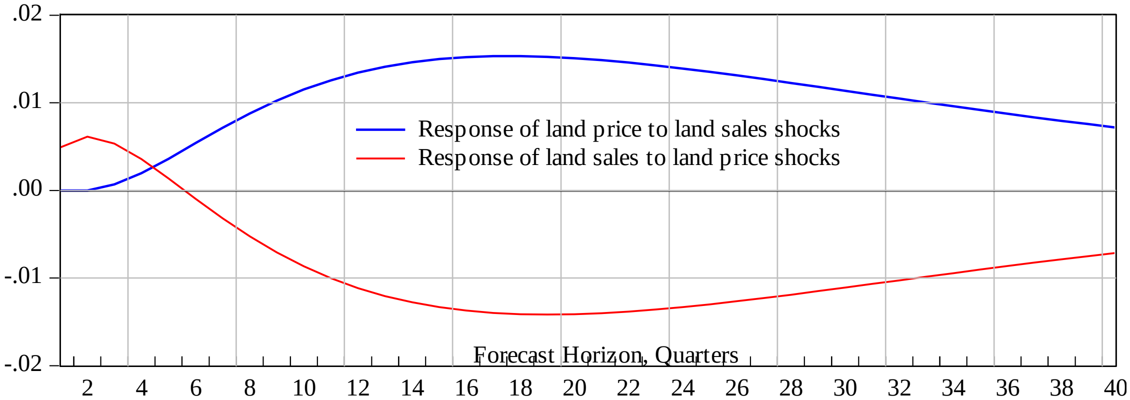
	Endogenous Variables		
	Sales	Price	Volume
Texas total income	0.170	0.205	0.375
Oil price	-0.191	0.373	0.183
Fed funds rate	-0.036	-0.247	-0.283

Source: Texas Real Estate Research Center's Texas Rural Land Econometric Model

Figures 1-5 present impulse response functions using WINRATS econometric software to obtain Cholesky factorization of variance-covariance matrix. Overall, land sales tend to overreact to shocks but quickly revert to the zero line. Land prices, on the other hand, have moderate responses but longer memories. The historical series of Texas land markets show land sales tend to react to changes before prices react in a similar direction.

Figure 1 presents the response of land prices to a one standard deviation shock in land sales and response of land sales to one standard deviation shock in land prices. The negative response of land sales suggests the land sales equation represents the demand side of the land market. The positive response of land prices to shocks in land sales suggests the land price equation represents the supply side of the rural land market. The outcome of these variables' responses—negative for land sales to land price and positive for land price to land sales—suggests the model conforms to a proper identification according to the VAR approach. Both responses have a sustained response following the initial shock, suggesting long memories in the state's rural land markets.

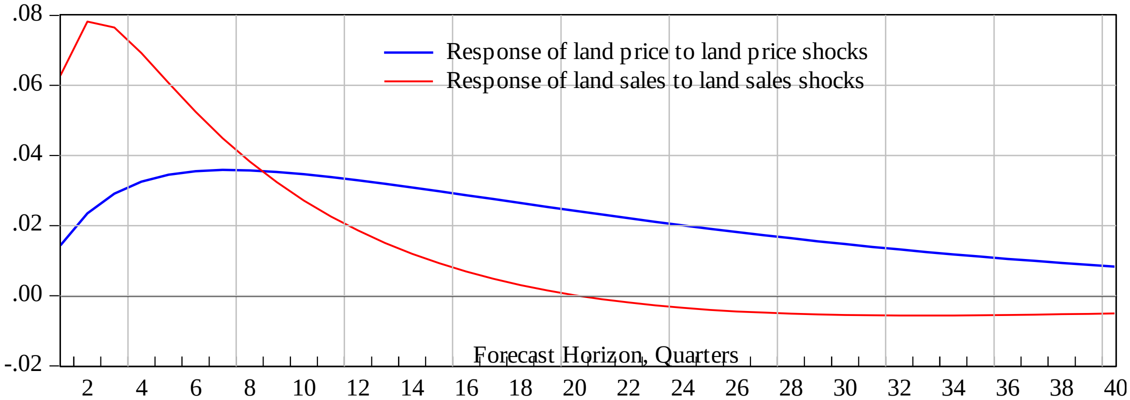
Figure 1. Response of Land Price to Land Sales Shocks and Response of Land Sales to Land Price Shocks



Source: Texas Real Estate Research Center's Texas Rural Land Econometric Model

Own responses (the response of land prices to land price shocks and land sales to land sales shocks) appear in Figure 2. Land sales overreact, producing an initial jump following the shock (red line in Figure 2). The series reverts to zero after four years and three quarters. In contrast, the more gradual yet sustained response of land prices shows a long-term persistence of the response of price-to-price shocks (blue line in Figure 2). Never reverting to zero, the response suggests a market with a long memory for land market prices.

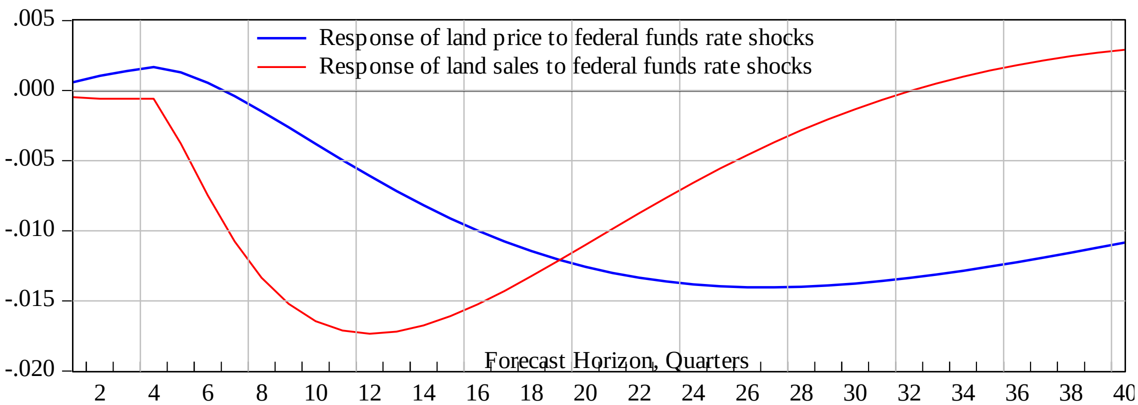
Figure 2. Response of Land Price to Land Price Shocks and Response of Land Sales to Land Sales Shocks



Source: Texas Real Estate Research Center’s Texas Rural Land Econometric Model

Both land prices and land quantities sold respond negatively to a positive shock in the fed funds rate (Figure 3). The gradual response of land price over time reveals a market response to the shock lasting more than 40 quarters (blue line in Figure 3). This price response to interest rates indicates a market with a long-memory pattern. However, land sales initially overreact then quickly return to the zero line after about eight years, a much shorter period.

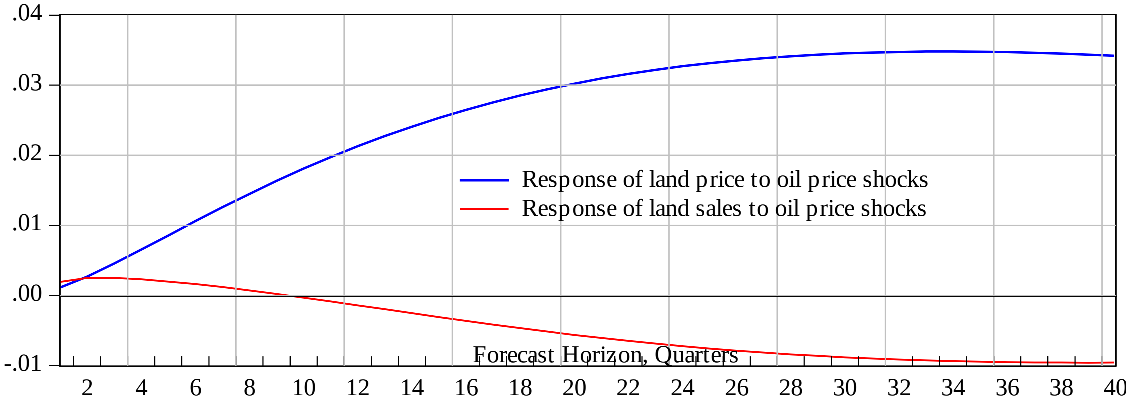
Figure 3. Responses of Land Prices and Land Sales to Fed Funds Rate Shocks



Source: Texas Real Estate Research Center’s Texas Rural Land Econometric Model

Land price responds positively to oil price shocks, an effect that also persists for a long time (Figure 4). However, the land sales response to oil price shocks, though initially positive, becomes negative after two years when the upward trend in land prices leads to reduced demand for land.

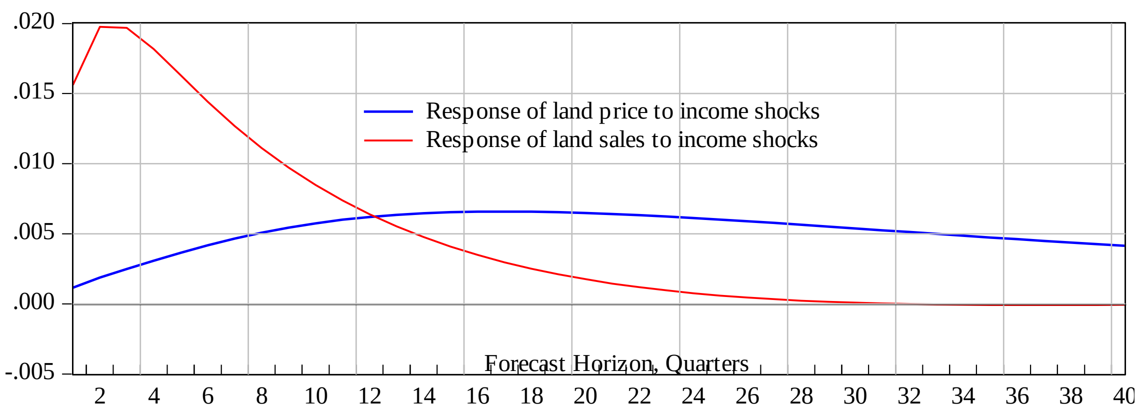
Figure 4. Responses of Land Prices and Lands Sales to Oil Price Shocks



Source: Texas Real Estate Research Center's Texas Rural Land Econometric Model

Both land price and land sales respond positively to Texas income shocks (Figure 5). Land price responds gradually but persistently and lasts a long time. By contrast, land sales overreact initially then lose momentum slowly.

Figure 5. Responses of Land Prices and Lands Sales to Texas Aggregate Income Shocks



Source: Texas Real Estate Research Center's Texas Rural Land Econometric Model

According to Shafir, Diamond, and Tversky, money illusion—when market participants disregard changes in currency purchasing power—can lead to price stickiness. The sustained response of land prices to shocks in land sales, own shocks, the fed funds rate, and Texas personal income are a sign of stickiness. The evidence of the existence of money illusion in the land market supports the use of nominal values in the modeling.

Table 5 presents the forecast error variance (FEV) decomposition results for land price. The small size of the percentages of squared prediction error in land price explained by the monetary policy rate suggests little shocks or unexpected changes in land price due to changes in the policy rate. News and rumors generally presage changes in the fed funds rate, so when the Fed changes the rate few surprises affect the market, which has already adjusted to the new rates. In addition, lending/borrowing processes in this market may take some time. Consequently, expected values of fed funds rates, as shown by long-run elasticities in Table 5, have a more important market impact than their shocks.

Table 5. Forecast Error Variance of Lands Prices Explained By:

Forecast Horizon	Fed Funds Rate	Oil Price	Texas Income	Land Price	Land Quantity
2	0.19	1.12	0.62	98.07	0.00
4	0.23	2.59	0.74	96.28	0.16
6	0.15	4.69	0.93	93.38	0.85
8	0.12	7.27	1.15	89.42	2.03
10	0.27	10.19	1.35	84.75	3.45
12	0.60	13.29	1.52	79.75	4.84
14	1.10	16.45	1.66	74.73	6.06
16	1.72	19.59	1.76	69.89	7.05
18	2.39	22.65	1.83	65.34	7.79
20	3.08	25.60	1.88	61.13	8.31
22	3.74	28.42	1.90	57.30	8.64
24	4.35	31.09	1.91	53.82	8.82
28	5.37	35.99	1.90	47.89	8.85
30	5.76	38.22	1.88	45.38	8.76
32	6.08	40.31	1.86	43.13	8.63
34	6.32	42.26	1.84	41.11	8.47
36	6.50	44.09	1.82	39.31	8.28
38	6.63	45.79	1.79	37.70	8.09
40	6.71	47.37	1.77	36.25	7.90

Source: Texas Real Estate Research Center's Texas Rural Land Econometric Model

Unexpected income changes also did not impress the state's land markets. Texas' aggregate income, excluding incomes from state's oil production, has been growing slowly like the rest of the

U.S. due to low wage growth rates. Consequently, there were few income surprises. By contrast, oil price moves have been the major source of shocks to Texas land prices, accounting for more that 18 percent of the squared prediction error of land price after 16 quarters and close to 45 percent in the longer term. These results agree with J.D. Hamilton's 2009, 2011, and 2013 findings about the impacts of oil price shocks on the U.S. economy. However, immediate impacts of oil price shocks on land prices remain small, less than 8 percent of the FEVs in the first two years following an oil shock. Own price shocks account for more than 86 percent of the FEVs in forecast horizons of one to eight quarters. Stickiness and persistence in land prices produce this result. Holding a non-depreciating asset, land sellers can employ a wait-and-see approach to marketing land. They can withdraw their land from the market in a buyer's market, opting to sell later. The significant shares of the FEVs of land prices accounted by its own FEVs again confirm a long memory pattern.

Shocks in fed funds rate, oil prices, incomes, and land prices presented in Table 6 account for about 25 percent of the FEVs of land sales in longer horizon. According to the sales equation, Texas income primarily directly drives Texas land sales. Due to impacts of oil prices on Texas income in equation (1.4), oil indirectly drives land sales. Land price stickiness puts the burden of supply and demand adjustments on land sales. As a result, more than 70 percent of the FEVs for land sales come from its own shocks.

Table 6. Forecast Error Variance of Lands Sales Explained By:

Forecast Horizon	Fed Funds Rate	Oil Price	Texas Income	Land Price	Land Quantity
2	0.01	0.09	5.89	0.57	93.44
4	0.01	0.10	6.09	0.46	93.34
6	0.25	0.10	6.26	0.36	93.04
8	1.10	0.09	6.34	0.43	92.04
10	2.42	0.08	6.35	0.75	90.40
12	3.88	0.09	6.30	1.31	88.42
14	5.23	0.11	6.23	2.06	86.37
16	6.33	0.16	6.14	2.92	84.45
18	7.12	0.26	6.04	3.83	82.75
20	7.64	0.39	5.95	4.72	81.29
22	7.93	0.57	5.87	5.57	80.05
24	8.06	0.80	5.79	6.34	79.01
26	8.08	1.06	5.72	7.02	78.11
28	8.04	1.36	5.66	7.61	77.33
30	7.97	1.69	5.60	8.10	76.64
32	7.89	2.04	5.54	8.51	76.01
34	7.82	2.41	5.49	8.84	75.44
36	7.76	2.78	5.44	9.11	74.91
38	7.72	3.16	5.40	9.31	74.41
40	7.69	3.53	5.36	9.47	73.95

Source: Texas Real Estate Research Center's Texas Rural Land Econometric Model

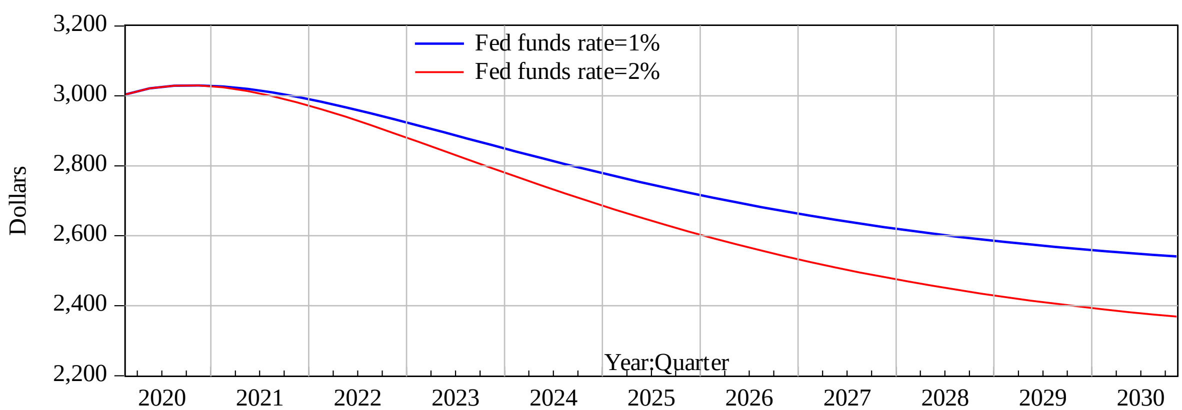
Model Simulations

Out-of-sample static simulations of the estimated model generate one-period-ahead forecasts of land price and land sales. However, stochastic dynamic simulations generate forecast trajectories of land prices and land sales along with standard deviations using Monte Carlo simulations with 1,000 draws from the posterior distribution of FEVs, according to K. Kloek and H.K. van Dijk. The model simulation requires forecasts of oil prices, fed funds rate, and total personal income in Texas exogenous variables in the model. Equations (1.3) to (1.5) can be used for forecasts of these variables. TRERC usually considers several optimistic or pessimistic scenarios about the future trajectories of these exogenous variables, using them as inputs for forecasting.

TRERC performed out-of-sample simulations of the estimated rural land model to investigate the impacts on trajectories of endogenous variables of their elasticities with respect to exogenous variables. Figures 6, 7, and 8 present forecasts of land price per acre, land sales in acres, and dollar volumes based on two fed funds rate trajectories for a forecast horizon from first quarter 2020 to fourth quarter 2030. One remains at 1 percent; the other increases to 2 percent. Both scenarios assumed oil prices of $40 per barrel and used equation (1.3) for Texas income.

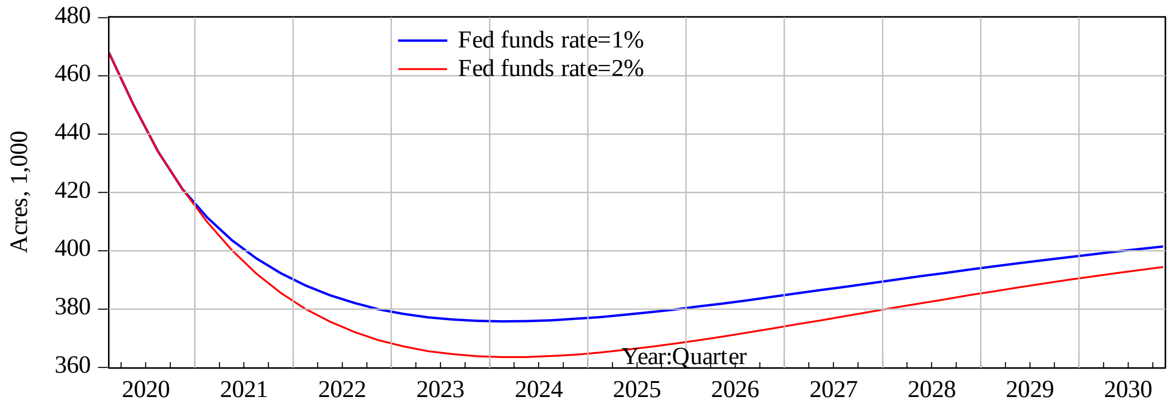
Figures 6, 7, 8 show land prices and land sales converge to their long-term steady states as predicted by their long-run elasticities in Table 3. Because of the four-quarter lag in the effect of the monetary policy rate, land prices are expected to trend upward until early 2021, followed by a downward trend (Figure 6). Forecasts of land sales are expected to continue their downward trend until 2024, then trend upward when lower land prices lead to higher demand for land (Figure 7). Dollar volumes of land sales are expected to follow a similar pattern (Figure 8).

Figure 6. Land Price Forecasts for 1 Percent or 2 Percent Fed Funds Rate



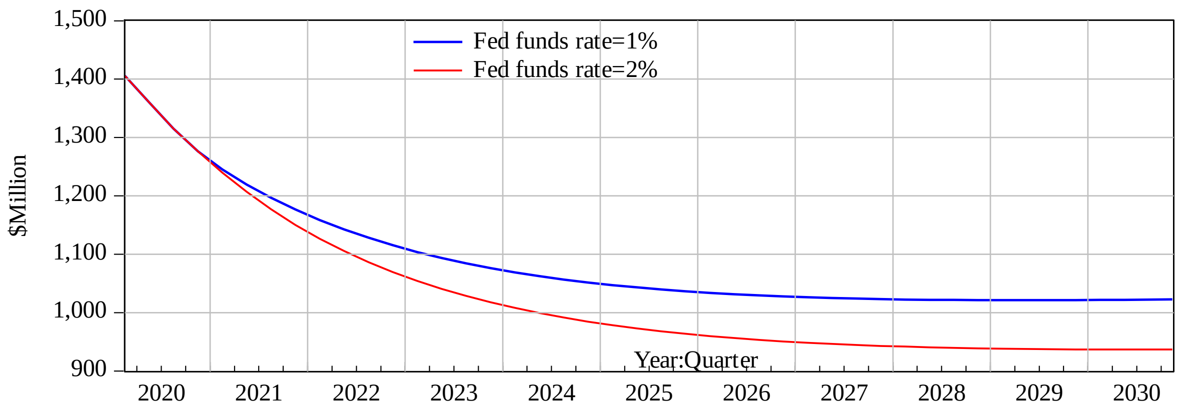
Source: Texas Real Estate Research Center's Texas Rural Land Econometric Model

Figure 7. Land Sales Forecasts, Acres, for 1 Percent or 2 Percent Fed Funds Rate



Source: Texas Real Estate Research Center's Texas Rural Land Econometric Model

Figure 8. Dollar Volume of Land Sales Forecasts for 1 Percent or 2 Percent Fed Funds Rate



Source: Texas Real Estate Research Center's Texas Rural Land Econometric Model

Summary and Conclusions

This paper presents an econometric model of Texas' rural land markets, built to provide a better understanding of the dynamics of those markets. Texas rural land markets reveal dynamics similar to those observed in general investment markets. These results contrast with the conventional paradigm focused on the illiquid and inflation-hedging qualities of rural land markets. The model demonstrates that general macro-economic factors (income, oil price, and fed funds rate) drive

Texas' rural land market trends, not the usual rural or agricultural financial drivers examined in most research.

The paper also finds market participants in the state's land market exhibit long price memories. Furthermore, they tend to think in nominal values as Texas total income, oil price, and the monetary policy rates serve as important economic influences affecting both land prices and land sales. Responses of land prices to shocks in these variables persists for a long time, suggesting a long memory and land price stickiness in the market. By contrast, land sales respond to the same variables in a more transitory manner. TRERC identified oil price fluctuations created the most uncertainty in this market. Out-of-sample simulations of the estimated model show convergence to long-term steady state equilibrium values for land price and land sales under different assumptions about the future state of exogenous variables. Taken together, the results make the model a useful framework for forecasting land prices and sales.

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