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Monetary Policy and the Housing Bubble

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Abstract The causes of the housing bubble are investigated using Granger causality analysis and VAR modeling methods. The study employs the S&P/Case-Shiller aggregate 10 city monthly housing price index, available in the period 1987–2010/8, the 20 city monthly housing price index for 2000–2010/8, and the federal funds rate data for the period 1987–2010/8. The findings are consistent with the view that the interest rate policy of the Federal Reserve in the period 2001–2004 that pushed down the federal funds rate and kept it artificially low was a cause of the housing price bubble.

Keywords Housing bubble · Granger causality · Impulse response function

Introduction

There is general agreement that the bursting of the housing price bubble in the US set off the severe financial crisis and deep recession of 2007–2009. Most observers were surprised by the fragility of the financial system and the resulting depth of the crisis that was initiated by the collapse of one sector of the financial system, the secondary home mortgage market. The literature on this episode is expanding rapidly, but more empirical research is needed. The purpose of this paper is to conduct an empirical test of the effect of monetary policy on an index of housing prices to determine the extent to which monetary policy produced the housing price bubble. Many observers blame the interest rate policy of the Federal Reserve Bank

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during the critical years of 2001–2004. Other observers do not place the Fed's interest rate policy at the center of the story.

The Financial Crisis Inquiry Commission (2011, pp. 84–85) observed that the Federal Reserve began lowering the federal funds rate from 6.60% in early 2001, and this rate reached a low point of 1.0% in August, 2003. The Commission (p. 85) states that

> Low rates cut the cost of homeownership: interest rates for the typical 30-year fixed-rate mortgage traditionally moved with the overnight fed funds rate, and from 2000 to 2003, this relationship held. By 2003, creditworthy home buyers could get fixed-rate mortgages for 5.2%, 3 percentage points lower than 3 years earlier. The savings were immediate and large.

The Commission goes on to note that interest rates on adjustable-rate mortgages were even lower and these loans became increasingly popular. As the Commission, Barth (2009), Zandi (2009), and many others have documented, the years immediately prior to the financial crisis were marked by loose standards for mortgage loans, rapidly expanding securitization of those loans (accompanied by moral hazard), ratings for mortgage-backed securities that were grossly inflated, and lax regulation.

This study examines the possible influence of the federal funds rate on the S&P/Case-Shiller Housing Price Indices using time-series methods. Monthly data from January, 1987 to August, 2010 are used. The basic finding is that Granger causality exists running from the federal funds rate to the housing price index, and that the effect is much stronger in the period beginning in the year 2000. This empirical method was employed by Bernanke and Blinder (1992) to investigate the channels of transmission of monetary policy. They found (1992, p. 905) that "… according to the Granger-causality criterion, the federal funds rate is far and away the best predictive variable (of macroeconomic variables) among the five considered."[1] Also Bernanke and Blinder (1992) used innovations in the federal funds rate as a measure of changes in policy, and found evidence that monetary policy partly operates through the supply of bank credit. After first discussing the theoretical issues, data are discussed, the model is developed, and the results are presented.

The Debate over Causes of the Housing Bubble

As one might have expected, prominent economists have different views about the primary causes of the housing bubble and subsequent financial crisis. Those views range from placing primary blame on the monetary policy of the Federal Reserve to

[1] The policy variables tested by Bernanke and Blinder (1992) included two measures of the money supply, the Treasury bill rate, and the 10-year Treasury bond rate. The macroeconomic variables included industrial production, capacity utilization, employment, unemployment rate, housing starts, personal income, retail sales, consumption, and durable-goods orders. Their tests consisted of forecasting each of these variables using six lags of the variable itself, the policy variable in question, and the consumer price index. The result that the federal funds rate Granger-causes housing starts suggests a similar result for housing prices.

citing a variety of factors that omits mention of the Fed entirely. Here is a sampling of the differing points of view.

Anna J. Schwartz, Milton Friedman's co-author on the iconic monetarist study *A Monetary History of the United States* (1963), blames expansive monetary policy. She states (2009, p. 19) that

> It has become a cliché to refer to the asset boom as a mania. The cliché, however, obscures why ordinary folk become avid buyers of whatever object has become the target of desire. An asset boom is propagated by an expansive monetary policy that lowers interest rates and induces borrowing beyond prudent bounds to acquire the asset. The Fed was accommodative too long from 2001 on and was slow to tighten monetary policy, delaying tightening until June 2004 and then ending the monthly 25 basis point increase in August 2006.

She also mentions other factors, such as Congress and Fannie Mae and Freddie Mac for promoting homeownership for low- and moderate-income borrowers, flawed financial innovations, and the rating agencies. But Fed interest rate policy is first on her list.

The Austrian economists agree. Austrian business cycle theory is based on Austrian capital theory, and posits that we alter the rate of interest produced by the free market at our peril. The market works well if the interest rate declines because the public has decided to save more, consume less now, and consume more in the future. However, if a decline in the interest rate has been engineered by the monetary authorities, the economy will be stretched in two inconsistent directions. A decline in the interest rate promotes an increase in investment projects, but also induces the public to save less. As Woods (2009, p. 74) puts it, "Investors have been misled into production lines that cannot be sustained." One has the image of condominium developments begun but not completed. The market eventually catches on, the prices of real capital assets fall, and a recession ensues. As Thornton (2009) points out, several Austrian economists made such predictions in 2003–2005. One implication of the theory that some allege is that the sooner the artificially low interest rate environment can be ended, the shorter and less painful will be the subsequent economic downturn. Attempts to prop up the situation will lead only to a worse crash. However, Austrian economists such as Thornton deny that an implication of this nature necessarily follows.

The late Milton Friedman would surely be in agreement with Anna Schwartz, and had common cause with the Austrians on many issues, but he believed that the Austrian business cycle theory does not pass the empirical test. Friedman (1993) reported on a series of empirical studies that he conducted over the years on whether a larger boom is followed by a larger contraction. His summary statement (1993, p. 171) is that, "There appears to be no systematic connection between the size of an expansion and of the succeeding contraction, whether the size is measured by physical volume or by dollar value." He goes on to note (1993, p. 172) that, "For one thing, it would cast grave doubt on those theories that see as the source of deep depression the excesses of the prior expansion (the Mises cycle theory is a clear example)." However, Skousen (2005) responds to Friedman by citing the recent examples of the tech boom and bust in the late 1990s and early 2000s, and the Japanese "lost decade" of the 1990s. And Thornton (2009) and Woods (2009) think that the facts of the latest boom and crash match the Austrian model well.

John Taylor (2009) argues that the Federal Reserve held the federal funds rate too low for too long during the critical years of 2002 through 2005, a time period that coincides roughly with the most rapid inflation in housing prices. He argues that, if the Federal Reserve instead had followed the "Taylor Rule," the boom and bust largely would have been avoided. The Taylor Rule states that the federal funds rate (r) should be set as follows:

$$r = 1 + 1.5\,p - 0.5\left[\frac{y^* - y}{y}\right] \tag{1}$$

where p is the rate of inflation (prior four quarters), y^* is full employment GDP, and y is actual GDP. Taylor (2009, p. 3) shows that the actual federal funds rate was below the Taylor Rule from the beginning of 2002 to the end of 2005, and as much as 3% below the Taylor Rule in the first quarter of 2004 (actual federal funds rate of 1% versus the Taylor Rule rate of 4%). A chart of the federal funds rate is shown below.

Shiller (2009), one economist who warned of the impending crisis, takes a very different position. His view is that the housing bubble began in 1997 and took off during a time when the federal funds rate fell slightly from 5.5% in 1997 to 4.75% for much of 1998, and then increased to 6.5% in 2000. Timing the housing bubble beginning in 1997 is consistent with the observation, made by Thornton (2009) and others, that the federal capital gains tax on the owner-occupied home essentially was eliminated in 1997. For a married couple the first $500,000 in appreciation ($250,000 for the single person) of the value of the home is exempt from taxation. Previously a one-time exemption on the cumulative appreciation on homes owned over the lifetime was provided for those over the age of 55. After 1997 people could speculate in houses virtually tax-free. Rather, Shiller argues that the housing bubble was a speculative boom that he calls (2008, p. 41) a "social contagion." Shiller (2009) recognizes that the period of very low federal funds rates coincided with the most rapid rise in housing prices. But he states that (2009, p. 48),

> We should not, however, view this period of very loose monetary policy as an exogenous cause of the bubble. For the monetary policy—both that of the Fed and that of other central banks around the world—was driven by economic conditions that were created by the bursting stock market bubble of the 1990s, and the real estate boom was itself in some ways a repercussion of that same stock market bubble.

He goes on to say (2009, p. 49) that

> The interest rate cuts cannot explain the general 9-year upward trend that we have seen in the housing market. The housing boom was three times as long as the period of low interest rates, and the housing boom was accelerating when the Fed was increasing interest rates in 1999. Moreover, long-term interest rates, which determine the rates for fixed-rate conventional mortgages, did not respond in any substantial way to these rate cuts until the late stages of the boom.

Furthermore, Shiller argues that many of the other alleged causes of the housing bubble—such as loose lending standards for home mortgages, wildly inaccurate ratings given to mortgage-backed securities, and the failure of regulating agencies to stop risky lending practices—were caused by the increasing housing prices, not the other way around. But he does suggest (2009, pp. 49–50), "So the rate cuts might have had the effect of boosting the boom, more than otherwise would have been the case, during its time of most rapid ascent, around 2004."

Paul Krugman (2009) sees it somewhat differently. He states (2009, p. 148), "We know why home prices started rising: interest rates were very low in the early years of this decade…" But then the rising home prices caused (2009, p. 148) "… a complete abandonment of traditional principles…" regarding mortgage lending practices. Loose credit standards fed the housing bubble, and rising home prices fed back into loose credit standards.

Housing experts Patric Hendershott, Robert Hendershott, and James Shilling (2010) blame the housing price bubble on what they call the mortgage finance bubble, which had two phases. They argue that first phase from 1997 to 2003 was caused largely by the expansion of the Government Sponsored Enterprises (Fannie Mae and Freddie Mac), which was accompanied by lending to (2010, p. 1) "… questionably qualified borrowers." The second phase from 2003 to 2007 resulted from the securitization of "junk" mortgages by both GSEs and private sector financial institutions. The Federal Reserve is not mentioned in their analysis until the March 2008 acquisition of Bear Stearns by JP Morgan Chase—with the assistance of the Fed.

Mark Zandi begins his analysis (2009, p. 9) with the following:

> The fuse for the subprime financial shock was set early in this decade, following the tech-stock bust, 9/11, and the invasions of Afghanistan and Iraq. With stock markets plunging and the nation in shock after the attack on the World Trade Center, the Federal Reserve Board (the Fed) slashed interest rates. By summer 2003, the federal funds rate—the one rate the Fed controls directly—was at a record low.

Zandi goes on to provide a catalog of other causes of the financial crisis, including the US trade deficit which produced a flood of foreign investment, low interest rates set by other central banks, financial innovations, rating agencies, and so on. But the fuse was the reduction of the Federal Funds rate to historic lows. Zandi (2009, p. 163) dates the housing price bubble from July 4, 2003—not 1997.

Nouriel Roubini, another economist who issued warnings of an impending crisis, argues that the catalyst for the housing price bubble was financial innovation. Roubini and Mihm (2010, p. 268) state that, "'Originate and distribute' became a vehicle for originating junk mortgages, slicing, dicing, and recombining them into toxic mortgage-backed securities, and then selling them as if they were AAA gold." In order for a bubble to grow investors need easy access to credit. The Federal Reserve obliged (2010, p. 169): "Greenspan slashed interest rates after September 11 and kept them too low too long. Banks and shadow banks leveraged themselves to the hilt, loaning out money as if risk had been banished." The Fed's interest rate policy may not have been the catalyst, but it is strongly implicated in the creation of the bubble.

Barth (2009, pp. 29–32) suggests the mechanism through which the drastic cut in the federal funds rate can be linked to the housing price bubble. He shows that there was a sharp decline in mortgage interest rates during the 2001 through the end of 2004, and that the interest rate on 1-year adjustable rate mortgages fell by a larger amount than did the interest rate on standard 30-year fixed rate mortgages—because short-term interest rates are highly correlated with the federal funds rate. The share of mortgages with adjustable rates increased as a result (with a lag), and many of those borrowers obtained sub-prime loans. Sub-prime loans are loans that have been granted to borrowers using weaker lending standards than had been used in the past. Adjustable rate loans were used because riskier borrowers called for a higher interest rate—beyond what many of them could afford. As Gorton (2010, p. 68) states:

> So the challenge was (and remains) to find a way to lend to such borrowers. The basic idea of a subprime loan recognizes that the dominant form of wealth of low-income households is potentially their home equity. If borrowers can lend to these households for a short time period, 2 or 3 years, at a high but affordable interest rate, and equity is built up in their homes, then the mortgage can be refinanced with a lower loan-to-value ratio, reflecting the embedded price appreciation.

The interest rate increase built into the mortgage was large enough to force the borrower to refinance after 2 or 3 years. Lenders are safe only if house prices rise.

The Data

This study makes use of two time-series data sets, the federal funds rate in the market, and the S&P/Case-Shiller Home Price Indices (2010). The S&P/Case-Shiller Home Price Indices for single-family home prices are generated and published monthly, and include 10 and 20 metropolitan area composite indices and indices for possible physical changes in the house. This study makes use of the composite indices for both the 10 and the 20 metropolitan areas and the individual indices for the 20 metropolitan areas. The 10 metropolitan areas in the composite index are Boston, Chicago, Denver, Las Vegas, Los Angeles, Miami, New York, San Diego, San Francisco, and Washington, DC. The other 10 metropolitan areas are Atlanta, Charlotte, Cleveland, Dallas, Detroit, Minneapolis, Phoenix, Portland, Seattle, and Tampa. A graph of the composite index for the 10 metropolitan areas is shown in Fig. 1. Both the index (January, 2000 = 100) and its natural log are shown from January, 1987 to August, 2010.

The index started at 62.82, increased 31.2% from 1/1987 to 10/1989, then drifted down slightly, but remained essentially unchanged up through 6/1997. The increase began in 1997. The index had increased by 24.6% through 1/2000. The index increased at an increasing rate; 23.9% from 1/2000 to 1/2002, 31.4% from 1/2002 to 1/2004, and 36.6% from 1/2004 to 1/2006. The peak of the index of 226.29 was attained in 6/2006 (an increase of 182.0% from 6/1997). The index began falling at that point—slowly at first and then more rapidly until the low point is reached in 6/09—and then displays an uneven recovery thereafter. The decline in the index began over a year prior to the official date of the beginning of the recession in 4Q 2007, but the low point of the index in 6/09 coincides with the official end of the recession in 2Q 2009.

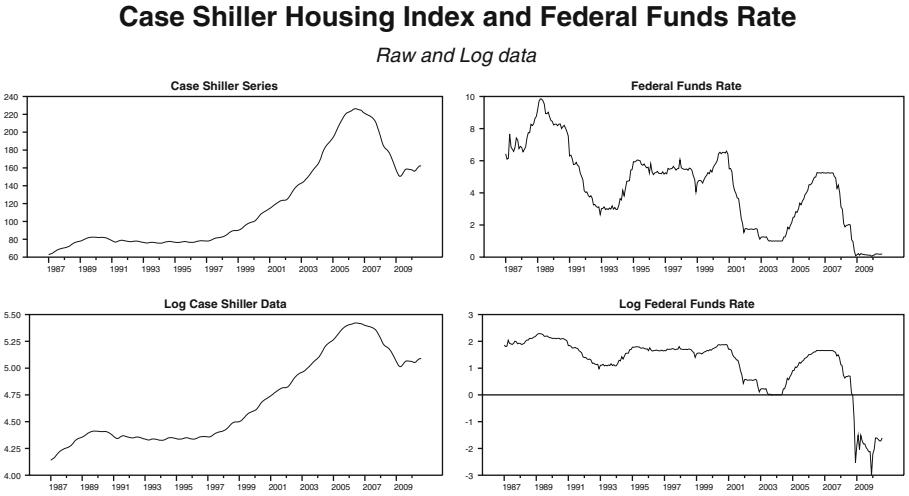

Fig. 1 Case Shiller Housing index and federal funds rate

The federal funds rate was obtained from EconStats. The world-wide web address is http://www.econstats.com/r/rusa_ew2.htm. The data are the Fed Funds market rates for the Friday closest to the end of the month in question. The market rate follows closely, but is not identical to, the Fed Funds target rate. Indeed, much of the time the Fed Funds target rate has a low end and a high end. The Fed Funds market rates from January, 1987 to October, 2010 in raw and natural log form are displayed in Fig. 1.

The federal funds rate increased sharply from 6.43% in 1/1987 to 9.84% in 4/1989 even as the home price index was increasing. From that high point the federal funds rate was cut steadily in response to the recession, and reached 2.96% in 6/1993. As Fig. 1 shows, the home price index barely moved during this time. The end of the recession of the early 1990s brought an increase in the federal funds rate to 6.05% in 4/1995. The rate moved within the range of 4.07% to 6.06% for the remainder of the 1990s, and stood at 6.60% in 12/2000. At this point the Federal Reserve began to reduce the federal funds rate aggressively—to 1.54% in 12/2001, and 1.00% in 8/2003. The rate was held steady at 1.00% up through 6/2004, at which time the rate began its steady rise to 5.25% in 6/2006. The rate remained at this level through 7/2007, and then dropped sharply in response to the financial crisis. The rate reached 0.10% in 12/2008, and remains at or below 0.20%.

This cursory examination of the data in Fig. 1 suggests that the home price index and the federal funds rate were uncorrelated from 1987 through 1997. During most of this period the home price index changed very little at the same time the federal funds rate moved sharply down and up. Home prices began their upward movement in 1997, and the federal funds rate did decline in 1998, but then increased in 1999 and 2000. The picture changes after 2000, when the steep drop in the federal funds rate coincides with the acceleration in the rise of the home price index. Furthermore, the subsequent peak in the federal funds rate in 6/2006 coincides with the beginning of the decline in the home price index. Lastly, the home price index stopped falling a few months after the federal funds rate hits its historic low point in 12/2008.

Data descriptions and summary statistics for the raw data are shown in Table 1 and plots of the raw data are shown for the 20 individual cities that make up the S&P/Case-Shiller 20 city composite index in Fig. 2. While the S&P/Case-Shiller 10 city composite index is available for the complete period 1987–2010/8 (284 observations), data are available only for 128 observations for Dallas, 236 observations for Detroit, 260 observations for Minneapolis, 236 observations for Atlanta and 260 for Phoenix limiting the 20 city composite series to 128 observations in the period 2000–2010/8. Inspection of Fig. 2 shows that while many of the city series follow a pattern similar to the aggregate 10 city S&P/Case-Shiller series shown in Fig. 1, there is some variation. For example Denver, Dallas and Boston seem not to have been as impacted by the down-turn in housing prices after 2006.

Model Estimation, Discussion, and Testing

As discussed in the prior section, there is substantial controversy over whether the Federal Reserve policy regarding the federal funds rate had an impact on the pattern of housing prices. Those arguing in favor of an effect stress that the reduction in the

Table 1 Data descriptions

Name	Description	Date	Mean	SD	Max	Min	# Obs
PHXR	Phoenix	1989	109.8	46.69	227.4	64.35	260
LXXR	Los Angeles	1987	128.7	62.86	273.9	59.33	284
SDXR	San Diego	1987	122.5	60.43	250.3	54.67	284
SFXR	San Francisco	1987	110.5	51.45	218.4	46.61	284
DNXR	Denver	1987	92.06	34.28	140.3	47.21	284
WDXR	Washington	1987	128.9	55.07	251.1	64.11	284
MIXR	Miami	1987	125.8	61.21	280.9	68.5	284
TPXR	Tampa	1987	118.8	46.86	238.1	77.33	284
ATXR	Atlanta	1991	101	21.28	136.5	69.05	236
CHXR	Chicago	1987	104.5	33.47	168.6	53.55	284
BOXR	Boston	1987	109.2	42.92	182.4	62.94	284
DEXR	Detroit	1991	91.46	22.73	127	57.63	236
MNXR	Minneapolis	1989	106.8	36.95	171.1	62.43	260
CRXR	Charlotte	1987	96.05	20.82	135.9	63.39	284
LVXR	Las Vegas	1987	115.4	49.61	234.8	65.14	284
NYXR	New York	1987	120.1	49.71	215.8	72.29	284
CEXR	Cleveland	1987	92.31	20.55	123.5	53.5	284
POXR	Portland	1987	101.4	42.67	186.5	40.96	284
DAXR	Dallas	2000	116.4	6.06	126.5	100	128
SEXR	Seattle	1990	109.9	40.17	192.3	58.23	248
CSXR	Case Shiller 10	1987	118.7	50.88	226.3	62.82	284
SPCS20R	Case Shiller 20	2000	155.5	32.05	206.5	100	128
FF_RATE	Federal Funds Rate	1987	4.411	2.425	9.85	0.05	284

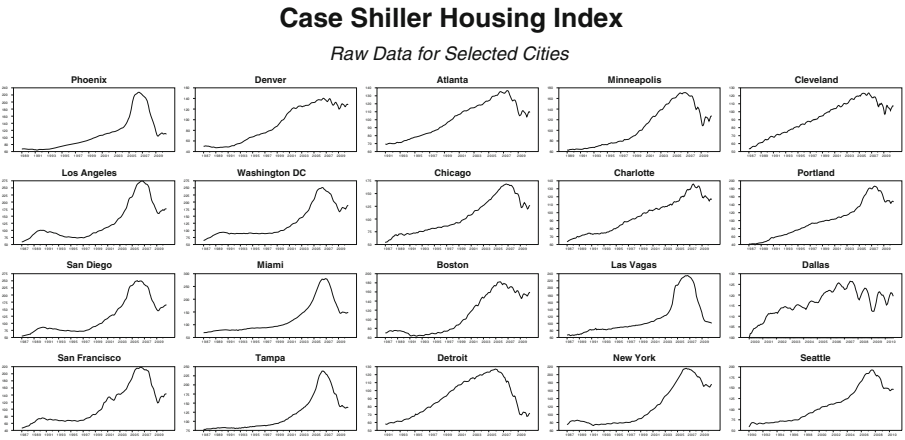

Fig. 2 Case Shiller Housing index

Fed Funds rate to 1% in 2003, and subsequently holding it down for a couple of years, "caused" the housing price bubble. In general Monetarists say yes while others such as Shiller say no, based on the notion that the bubble started well before 2003 in the late 90s. To investigate what to believe, the 10 city aggregate series, the 20 city aggregate series and the 20 individual city series are studied.

Given that y_t = the composite housing price index in period t and x_t = the federal funds rate, x_t will Granger (1969) cause y_t if a model

$$y_t = a + \sum_{i=1}^{m} \gamma_i B^i y_t + \sum_{i=1}^{m} \delta_i B^i x_t + e_t \tag{2}$$

has a significantly lower error sum of squares than a model that restricts δ_i=0, for i=1,…,m where B is the lag operator defined such as $B^i x_t \equiv x_{t-i}$ as in Greene (2008, p. 699). In order to use Eq. 2 to test for Granger causality the lag m must be set sufficiently long so as to remove all significant autocorrelation in the error term e_t.

An alternative way to proceed that includes the possibility of feedback from y to x is to use a VAR model of the form

$$\Phi(B)\begin{bmatrix} x_t \\ y_t \end{bmatrix} = \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \tag{3}$$

which can be written as

$$\begin{bmatrix} \phi_{11}(B)\ \phi_{12}(B) \\ \phi_{21}(B)\ \phi_{22}(B) \end{bmatrix}\begin{bmatrix} x_t \\ y_t \end{bmatrix} = \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \tag{4}$$

where Granger causality from x to y implies that $\phi_{21}(B)\neq 0$ where $\phi_{ij}(B)$ is a polynomial in the lag operator B with m terms. Zellner and Palm (1974) have a

detailed discussion of the relationship between these alternatives models, both of which have their uses. For example Eq. 2 can be written

$$(1 - \sum_{i=1}^{m} \gamma_i B^i) y_t = (a + \sum_{i=1}^{m} \delta_i B^i) x_t + e_t \tag{5}$$

which can be simplified to

$$\gamma(B) y_t = \delta(B) x_t + e_t. \tag{6}$$

Provided that $\gamma(B)$ is invertible ($\sum_{j=1}^{\infty} |\gamma_i| < \infty$), Eq. 6 can be expressed as a rational distributed lag or transfer function, as in Box et al. (2008); i.e.,

$$y_t = \frac{\delta(B)}{\gamma(B)} x_t + \frac{1}{\gamma(B)} e_t \tag{7}$$

The term $\frac{\delta(B)}{\gamma(B)}$ measures the effect of x_t on y_t taking into account both the effect of lags of x_t on lags of y_t and the direct effects of lags of x_t on y_t and is called the impulse response function by Box et al. (2008, p. 13). Often of interest is the effect of a shock in the x and y equations. To measure this effect requires transforming the VAR model in Eq. 3 to a VMA model, given $\Phi(B)$ is invertible, or

$$\begin{bmatrix} x_t \\ y_t \end{bmatrix} = \Theta(B) \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \tag{8}$$

where $\Theta(B) \equiv [\Phi(B)]^{-1}$. The terms in $\Theta(B)$ measure the dynamic response of each of the endogenous variables to a shock to the system. Eq. 8 can be expanded to

$$\begin{bmatrix} x_t \\ y_t \end{bmatrix} = \begin{bmatrix} \theta_{11}(B) & \theta_{12}(B) \\ \theta_{21}(B) & \theta_{22}(B) \end{bmatrix} \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \tag{9}$$

where if x_t is the log of the federal funds rate and y_t is the log of the housing price series. The term $\theta_{21}(B)$ measures the effect of shocks in the log federal funds market on the log housing price. If $\theta_{ij}(B)=0$ for $i \neq j$ then each endogenous variable is not impacted from shocks coming from the other endogenous variable. Theory would suggest that shocks from the interest side would have a negative effect on housing prices, resulting in $\theta_{21}(B)<0$, but that positive shocks coming from the housing market would tend to bid up interest rates, resulting in $\theta_{12}(B)>0$. To investigate this possibility later in the results section of this paper Rats software version 8.0 routine @mcgraphirf, Doan (2010a, p. 495), is used to calculate using Monte Carlo integration $\theta_{ij}(B)$ for all four possible cases with 95% bounds.

In general the number of lags in VAR model m is not the number of lags in $\theta_{ij}(B)$ which we will call q. In the results reported later, $m=16$ and $q=20$ although the

pattern is basically the same if $m=12$. B34S version 8.11 F was used to calculate the other results reported in the paper see Stokes (1991).

Results

Using the data of this paper, m was set as 12 so as to remove all significant autocorrelations and cross correlations in the estimated VAR residuals. Granger causality tests using this setup are listed in Table 2. Logs of both the interest rate series and housing series are used. Model 1 reports results in the period 2000–2010/8 using the 10 city housing price series and finds the log of the federal funds rate significantly (.996985) Granger-causes the housing series. Model 2 removes 12 observations for 1999 to be compatible with that which can be obtained in model 6 with the 20 city composite series that is only available starting with 2000/1, and again finds the log of the federal funds rate significantly (.997648) Granger-causes the log housing series. To remove the possibility that this finding in the latter period is sensitive to the housing series used, the 20 city series is used in model 6. Here the significance is .995032. The above findings suggest that in the 2000–2010/8 period the log federal funds rate Granger-causes the housing series.

The next question is whether the effect was stronger in the earlier period, the later period or equally strong in both periods. These questions are addressed in model 4 for the whole period where the significance was .999999 and in model 3 which is restricted to the earlier period 1987–1999/12 period, and shows a significance level of .918631. Model 5 uses the period 1987–2000/12, which is available for the 10 city data series but not for the 20 city data series (that also loses the year 2000 due to lags). Again the significance was .914226. In summary the Granger-causality results are consistent with the view that it was Federal Reserve lowering the interest rate and

Table 2 Granger causality tests of LNFFRATE

Model	Period	USS	RSS	F Test	Significance
ln_CSXR = f(lag (LN_CSXR), lag(LNFFRATE))					
1	2000–2010/8	.0007308	.0009631	F(12,103)=2.7299	.996985
2	2000–2010/8	.0006626	.0009109	F(12,91) = 2.8420	.997648
3	1987–1999/12	.0004289	.0005065	F(12,120)=1.6719	.918631
4	1987–2010/8	.0012730	.0051148	F(12,247)=5.1148	.999999
5	1987–2000/12	.0004803	.0005523	F(12,132)=1.1648	.914226
LSPCS20R = f(lag(LSPCS20R), lag(LNFFRATE))					
6	2000–2010/8	.00060106	.000808	F(12,91)=2.60762	.995032

For variable descriptions see Table 1. USS = unrestricted sum of squares. RSS = restricted sum of squares obtained by removing the lags of the log of the Federal Funds Rate. The number of lags is assumed to be 12. Thus a model starting in 2000 will actually be starting in 2001 after observations are deleted due to lags. Model 1 starts exactly in 2000/1 since no observations have to be deleted due to data being available from 1987/1 for both series. To be comparable with model 6 which starts in 2001/1 due to dropped observations, model 2 is estimated dropping 12 observations. Model 5 is the same as model 2 except for the fact that one more year (2000) is added

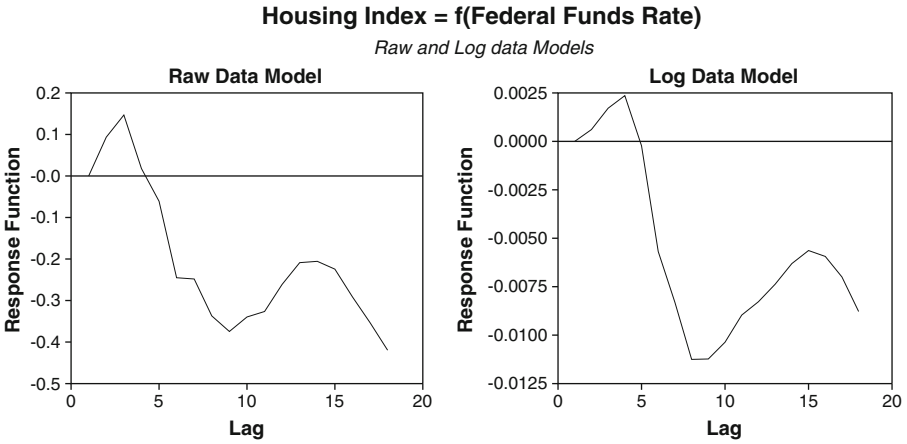

Fig. 3 Housing index = f(Federal Funds Rate)

holding it down in the period 2001–2004 that significantly helped cause the housing bubble. These results are also consistent with the hypothesis that there was a change in the relationship between the federal funds rate and housing prices after 2000. Such a change may have been related to changes in the mortgage market—loose credit standards, increasing securitization, lax regulation, et al.

While the above findings are consistent with the federal funds rate policy of the Federal Reserve having an impact on the housing bubble, these results do not address the exact nature of the relationship. Recall that the hypothesis is that a reduction in the log federal funds rate caused log housing prices to increase. Using the 10 city housing data, $\delta(B)/\gamma(B)$ from Eq. 7, or what Box et al. (2008, p. 13) call the impulse response, is calculated for both raw and log data in the period 1987–2010/8 and displayed in Fig. 3. The impulse response is found to be negative, which is consistent with the monetary model that postulated that a decrease (increase) in the interest rate series, whether defined in raw terms of log form, will have a positive

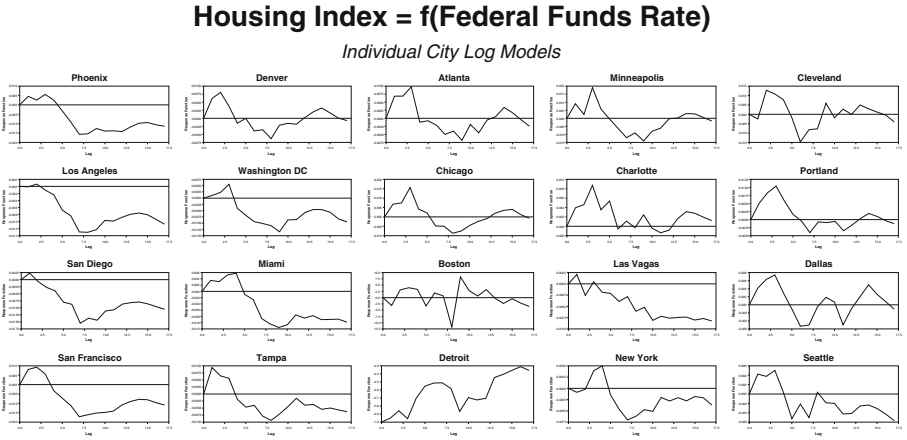

Fig. 4 Housing index = f(Federal Funds Rate)

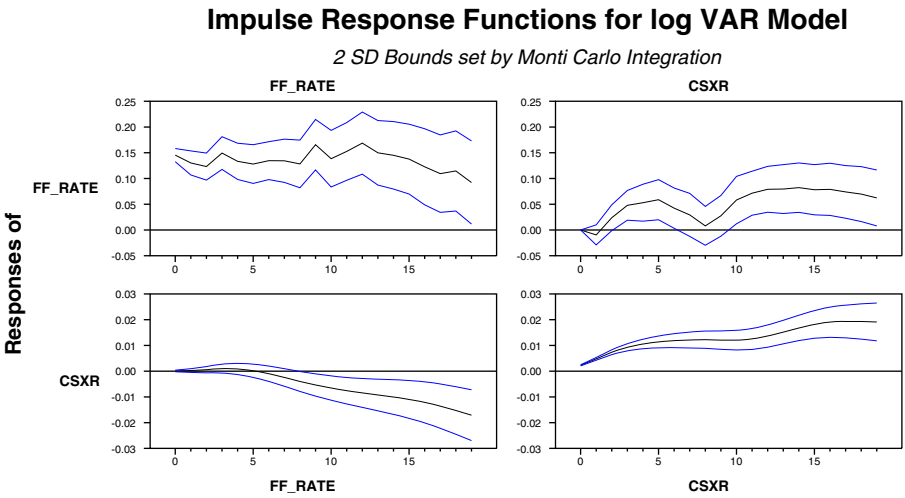

Fig. 5 Impulse response functions for log VAR model

(negative) effect on the housing series whether in raw or log form. Both models show a maximum response after 8 to 9 months.

Figure 4 shows the estimated impulse response pattern $\delta(B)/\gamma(B)$ for each of the 20 cities using the maximum number of observations available over the periods listed in Table 1. In most cases the pattern was negative, although there are differences by city. The largest and most sustained negative effects occurred in Phoenix, Los Angeles, San Diego, San Francisco, Miami, and Las Vegas. The results reported thus far in Figs. 3 and 4 pertain only to the effect of changes in the federal funds rate on the housing price series.

The effect of shocks in the federal funds market and the housing market on equilibrium in the system is investigated next. For this we turn to the estimation of $\Theta(B)$ in Eq. 9, which is reported in Fig. 5. Doan (2010b, p. 495) discusses the details of the Monte Carlo procedure used to obtain estimates of the 95% confidence intervals of $\theta_{ij}(B)$, $i=1$, $2j=1$, 2 and should be consulted for details. As noted earlier the number of lags on the VAR side (m) was 16, the number of lags on the VRA side (q) was 20, and 10,000 draws were made. In Fig. 5 $\theta_{11}(B)$ shows a positive effect of federal funds rate shocks on the federal funds rate. The results for $\theta_{12}(B)$ measure the feedback of housing shocks on the federal funds rate, which is significantly positive for lags 3–6 and 17–20. The results for $\theta_{21}(B)$ were found to be significantly negative after lag 7, suggesting that a positive shock to the federal funds rate will be reflected in housing prices significantly moving down in 7 months and continuing up to 20 months. Finally as expected $\theta_{22}(B)$ is significantly positive, which is consistent with bubble psychology.[2]

[2] See Mikhed and Zemcik (2009) for detailed tests for the presence of bubbles in U.S. metropolitan housing markets from 1978 to 2006 using data on price-rent ratios. Their results suggest the presence of housing price bubbles in the late 1980s, the early 1990s, and from the late 1990s to 2006. See Das et al. (2010) for time-series forecasting models of housing prices at the census division level. Several studies have used time-series methods to study housing permits and starts, the most recent of which is Vargas-Silva (2008).

Conclusion

Granger causality results using both the 10 city and 20 city S&P/Case-Shiller housing price indices are consistent with the hypothesis that the interest rate policy of the Federal Reserve that lowered and held down the federal funds rate in the period 2001–2004 was at least one important cause of the housing bubble. The results also suggest that the sharp increase in the federal funds rate during 2004–2006 was a cause of the subsequent decline in housing prices. Impulse response models were estimated for both aggregate and 20 city models over the maximum data period available. In general the findings are consistent with those that argue that the log federal funds rate is negatively related to the log housing price series. Using Monte Carlo integration a VAR model was estimated for the aggregate 10 city series data for the period 1987 to 2010/8 and inverted to form a VMA model with 95% confidence bounds. The results show that positive shocks in the federal funds equation have a negative effect on housing prices, and that positive shocks in the housing equation positively impact the federal funds rate. Positive shocks in the housing price equation increase housing prices, a result consistent with the existence of a housing price bubble. The basic result of the study is that monetary policy as implemented through the federal funds rate contributed both to the housing price bubble and to the subsequent decline in housing prices.

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