

# High-Frequency Impact of Monetary Policy and Macroeconomic Surprises on US MSAs and Aggregate US Housing Returns and Volatility: A GJR-GARCH Approach

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## Abstract

This paper explores the impact of monetary policy and macroeconomic surprises on the U.S housing market returns and volatility at the Metropolitan Statistical Area (MSA) and aggregate level using a Glosten–Jagannathan–Runkle generalized autoregressive conditional heteroscedasticity (GJR-GARCH) model. Using daily data and sampling periods which cover both the conventional and unconventional monetary policy periods, empirical results show that monetary policy surprises have a greater impact on the volatility of housing market returns across time with particularly pronounced effect during the conventional monetary policy period. We also show that macroeconomic surprises do not have a significant impact on housing returns for most MSAs for the full sample, conventional and unconventional monetary policy periods.

**Keywords:** Monetary policy and macroeconomic surprises; Asymmetric GARCH; Housing market returns and volatility.

**JEL Classifications:** C32, E32, E44, E52, R31.

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## **1. Introduction**

Residential homes are the largest financial asset holding in the portfolios of most U.S households (specifically, about half of total household net worth), hence changes in homeowner equity can impact the individual's wealth and the overall economy (Iacoviello, 2012). The housing market has an impact on the consumers through the wealth effect, and on the financial sector through the mortgage market and activities from the management of investor portfolios. Thus, house price movements are vital in driving the broader macroeconomic outcomes. There is a general consensus that housing prices are a good indicator of economic recovery as they reflect the level of consumers' confidence (Wang, 2014). As such, timely measures of housing price movements contain important information concerning the current state of the economy.

This highlights the need to fully understand the house price movements and the factors that drive the housing markets. Housing, being a consumption as well as an investment asset, intuitively is driven by interest rates and the news reflecting macroeconomic fundamentals (Kishor and Marfatia, 2017). Moreover, the arrival of new information about the factors that drive house prices and the timing of measuring the house price data is mostly non-synchronous. This makes it necessary to undertake a high-frequency analysis of house price responses to macroeconomic and policy announcements. This paper investigates the high-frequency impact of the surprise component of monetary policy (Federal funds rate) as well as macroeconomic surprises on 10 U.S Metropolitan Statistical Areas (MSAs) housing market returns and volatility. The study further investigates this impact on an aggregate level, and analyzes how the results compare to the impact on stocks using the Standard & Poor's 500 (S&P500), and also aggregate Real Estate Investment Trusts (REITs) market. Given the typical nature of volatility clustering of high frequency asset returns, we apply the Glosten-Jagannathan-Runkle generalized autoregressive conditional

heteroscedasticity (GJR-GARCH) model (Glosten et al., 1993) to examine the impact of monetary policy and macroeconomic surprises on the returns and volatility in the housing market at both individual MSA and aggregate level, using daily data of the housing market.

One of the main contributions of this paper is that it uses new high-frequency daily data of the housing market, which is not easily available. Apart from this dataset, Wang (2014) notes that housing market data is mostly available in relatively low monthly and quarterly frequencies, compared to other financial assets. Such low-frequency data tends to underestimate housing market risk as it ignores the information in the within variations in housing prices (Wang, 2014). In addition, the use of high-frequency daily housing data allows us to estimate a more accurate measure of not only housing returns but also of the volatility in the housing markets. Understanding the dynamics of housing volatilities and its response to the surprise component of monetary policy and macroeconomic surprises is important since housing asset plays a significant role in the investor's optimal portfolio decision (Yao and Zhang, 2005).

In the present study, the sample period varies for the different MSAs, mostly starting in 1995 - 2012 for most MSAs and the aggregate sample period starting in 2001 – 2012. This sample period allows us to cover the period when the Federal Reserve applied conventional monetary policy as well as the period when the short-term nominal interest rates were at or near the zero lower bound and unconventional monetary policy tools were implemented. In order to fully uncover how these changes in policy tools impact housing markets, we undertake the analysis for the full sample period, the conventional monetary policy period which constitutes the start of the dataset to December 2008, and the sample period from 2009-2012 representing the period the Federal Reserve started to use unconventional methods of monetary policy.

In efficient markets, asset prices respond to new information, therefore it is important to measure the surprise component of that information and the uncertainty that results from it (Scotti, 2016). According to Kroencke et al., (2016), there exists two transmission channels through which asset markets can be affected by macroeconomic information risk. Firstly, news on macroeconomic data is sometimes published randomly and secondly, the arrival of news announcements of macroeconomic variables and policy actions occurs on a pre-scheduled date, therefore the exact value of these factors can only be predicted. In light of this, it is essential to measure expectations contained in the macroeconomic and policy announcements.

One of the reliable and trusted sources of the predicted values macroeconomic announcements is the consensus estimations of professionals (Marfatia et al., 2017). Based on the semi-strong form of the efficient market hypothesis, the pricing of an asset already includes forecasted values after the publication of consensus data, but not the unanticipated difference between the predicted and the announced, which is the surprise component. To measure the monetary policy surprise, it is found that the Federal (Fed) funds futures rate is a natural market-based proxy of the otherwise unobserved market expectations of the Federal Reserve policy actions (Kuttner 2001; Kishor and Marfatia, 2013). All the expectations of the future changes in the interest are expected to be captured by the Fed funds futures rate. Therefore, any change in this futures rate after the Federal Open Market Committee (FOMC) meeting is because the announcement rate change (or no change) measures the unexpected (surprise) changes in the monetary policy. These monetary policy surprises are found to have a statistically significant impact on the returns on financial assets (Marfatia et al., 2017).

It is not surprising that several studies focus on analyzing the impact of domestic and U.S monetary policy and macroeconomic news surprises on bonds, commodity, currency, equity markets, and REITs market (see for example, Kishor and Marfatia, 2013; Cakan et al.,

2015; Caporale et al., 2017; Scotti, 2016). However, in spite of the central role of housing markets, there is almost no literature on the study of the high-frequency impact of both monetary policy and macroeconomic surprises on the general housing market. However, there is a relatively sparse literature focusing on the real estate investment trusts (REITs) market returns (see for example, Bredin et al., 2011; Xu and Yang, 2011; Claus et al., 2014; Kroencke et al., 2016; Marfatia et al., 2017)<sup>1</sup>, which to some extent, is understandable, given that daily data on house prices was not available until recently.<sup>2</sup> REITs market is indeed associated with the real estate market, but characteristically different from it, and is much similar to standard equity markets like S&P500 with REIT market capturing partial<sup>3</sup> movements in primarily non-residential (commercial) properties which include apartments, industrial properties, offices, and retail properties (Ghysels et al., 2013). Institutions and individuals can take positions in the commercial real estate market by investing in publicly-traded REIT companies. Market-based indices can be obtained from the trading of individual REIT stocks. These indices are usually constructed as value-weighted averages of firm-specific REIT returns. Residential house prices movements tend to capture housing wealth, with REITs associated with the financial wealth variability, but the former is the dominant part in household's net worth. Also, as pointed out by Iacoviello (2012), 80 percent of housing wealth is made up by the stock of owner-occupied homes, with the remaining 20 percent of the residential real estate held by nonfarm noncorporate businesses, which is made up by the rental housing stock. Hence, by looking at housing price reactions to monetary policy and macroeconomic surprises, we are essentially concentrating on owner-occupied

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<sup>1</sup> Gabriel and Lutz (2017) analysed the impact of unconventional monetary policy surprises on mortgage default risks.

<sup>2</sup> Of course there is a large literature that has analysed the impact of macroeconomic and monetary policy shocks on the US housing market at monthly, quarterly and annual frequencies using Vector Autoregressive (VAR) models (see for example, Simo-Kengne et al., (2014), Rahal (2016), Plakandaras et al., (2017) and Gupta and Marfatia (forthcoming) for detailed reviews in this regard).

<sup>3</sup> Note that REITs represent quite a small fraction of estimated value of non-residential real estate market. Hence, REITs may not constitute a representative sample of the U.S. commercial real estate market as a whole.

homes used mainly for residential purposes (i.e., consumption), and also to a limited degree for investment.

To the best of our knowledge, this is the first paper to analyze monetary policy (both conventional and unconventional) and macroeconomic surprises on high-frequency movements (returns and volatility) of the housing markets of 10 US MSAs, besides the aggregate market. The remainder of the paper is organized as follows: Section 2 presents the data, while Section 3 discusses the model and empirical results, with Section 4 concluding the paper.

## **2. Data**

This study uses daily housing returns based on a new set daily housing price series constructed by Bollerslev et al., (2016) using the repeat sales method<sup>4</sup> (Shiller, 1991) and comprehensive housing transaction data from DataQuick. The daily housing price series covers the all of the 10 MSAs. Following Wang (2014), we use the daily Composite 10 Housing Index ( $P_{c,t} = \sum_{i=1}^{10} w_i P_{i,t}$ ) as a proxy for the aggregate housing price computed as a weighted average. The 10 MSAs and the specific values of the weights ( $w_i$ ) are Boston (0.212), Chicago (0.074), Denver (0.089), Las Vegas (0.037), Los Angeles (0.050), Miami (0.015), New York (0.055), San Diego (0.118), San Francisco (0.272), and Washington D.C. (0.078), representing the total aggregate value of the housing stock in the 10 MSAs in the year 2000 (see Wang (2014)). The S&P500 equity and S&P REIT indices data are obtained from Datastream of Thomson Reuters.

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<sup>4</sup> Repeat sales methodology is used to estimate house price changes by evaluating repeat transactions of the same house, assuming that the quality of the same house remains the same over time unless there are records of significant renovations and reconstruction. The advantages of this method is that it controls for the heterogeneity in characteristics of houses and the estimation only requires data transaction prices and sales dates for properties (Wang, 2014).

For the macroeconomic surprises, we follow the daily macroeconomic index by Scotti (2016) which is constructed using a dynamic factor model and business condition indexes to estimate the weights of the contribution of the economic indicator, which include: quarterly Gross Domestic Product (GDP), monthly industrial production (IP), employees on non-agriculture payroll, monthly retail sales and the monthly Institute of Supply Management (ISM) manufacturing index to these business condition indexes. The weights are then used to average surprises to construct the macroeconomic surprise index (see Scotti, 2016 for details on the construction of the index).

For the monetary policy surprise, we use the monetary policy shock measure by Nakamura and Steinsson (2018). They construct a monetary policy shock dataset using data on changes in the prices of federal funds futures rate over a 30-minute window around FOMC announcements (see Appendix A in Nakamura and Steinsson (2018)).

Summary statistics of the housing log returns, S&P500 log returns, monetary policy and macroeconomic surprises for the 10 MSA and aggregate daily data are presented in Table A1 in the Appendix, along with the respective length of data availability. Figure A1 in Appendix plots of the data used. Note that, our data heterogeneously covers the period of June, 1995 to October, 2012, with the end point being a month after the third phase of the Quantitative Easing was announced by the Federal Reserve on 13<sup>th</sup> September of 2012, and with tapering talks starting in the June of the following year. The sample period of the daily housing indices is understandably determined by its availability based on the work of Bollerslev et al., (2016). The sample mean for the daily housing returns as well as the mean macroeconomic surprise is generally positive, while the mean of monetary policy surprise and S&P500 returns are negative, with all the variables being non-normal as suggested by the Jarque-Bera test. Interestingly, the REITs return is more volatile than equity and aggregate housing market returns over the common sample period.

### 3. Methodology and Empirical Results

In this paper, we use the GJR-GARCH model proposed by Glosten, Jagannathan and Runkle (1993) to examine the impact of monetary policy and macroeconomic surprises on housing market returns and volatility at daily frequency for both individual MSA and aggregate levels. The GJR-GARCH model is preferred for this analysis because it is designed to capture an important phenomenon in the conditional variance of assets, which is the leverage effect captured by the asymmetric terms. Since future increases in the volatility of returns are associated with present falls in asset prices, in order to capture the statistical leverage effect, which is the propensity for the volatility to rise more subsequent to large negative shocks than to large positive shocks, we use the following GJR-GARCH specification following Wang (2014):

$$R_t = \mu + \rho R_{t-1} + \gamma_0 MP_{t-1} + \gamma_1 MS_{t-1} + \varepsilon_t \quad (1)$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \varepsilon_{t-1}^2 d_{t-1} + \beta_0 h_{t-1} + d_1 MP_{t-1} + d_2 MS_{t-1} \quad (2)$$

$R_t$  represents the U.S housing return series,  $MP$  is the federal funds rate monetary policy surprise,  $MS$  represents the macroeconomic surprise and  $\varepsilon_t$  is the stochastic disturbance term that is assumed to be normally distributed with zero mean. The conditional variance  $h_t$  depends on the mean volatility level ( $\alpha_0$ ), the lagged error ( $\varepsilon_{t-1}^2$ ) and the lagged conditional variance ( $h_{t-1}$ ). The asymmetric effect is captured by the  $\varepsilon_{t-1}^2 d_{t-1}$  term, where  $d_t = 1$  if  $\varepsilon_t^2 < 0$ ; and  $d_t = 0$  otherwise. The shocks have an asymmetric impact on conditional variance if  $\alpha_2$  is statistically significant.

Table 1 present the summary of estimation results revealing the positive and negative impact of monetary policy and macroeconomic surprises on housing returns and volatility. The full set of GJR-GARCH estimation results of the impact of monetary policy and macroeconomic



surprises on housing returns and volatility is presented in Table A2 in the Appendix. The results show that for the full sample, monetary policy shocks do not statistically impact housing returns for 6 of the 10 U.S MSAs<sup>5</sup>. Similarly, for the period when the conventional monetary policy was implemented, evidence suggests that monetary policy shocks do not statistically impact housing returns for 7 of the 10 U.S MSAs<sup>6</sup>, with a positive and statistically significant relationship for Miami. For the unconventional monetary policy period, monetary policy shocks also do not statistically impact most of the U.S MSAs, except for Washington which shows a significant relationship.

**Table 1: GJR-GARCH model estimation summary results of significant results of the impact of monetary and macroeconomic surprises on housing returns and volatility**

**Panel A: Positive Effects**

Metropolitan Area	Sample period	Monetary policy surprise		Macroeconomic surprise	
		Returns	Volatility	Returns	Volatility
Chicago	$P_2$	_____	2.500** (0.012)	_____	_____
Denver	$P_1$	_____	16.023*** (0.000)	_____	_____
	$P_2$	2.589** (0.010)	_____	_____	_____
Las Vegas	$P_2$	_____	_____	_____	1.777* (0.076)
	$P_3$	_____	_____	_____	3.336*** (0.001)
Los Angeles	$P_1$	_____	_____	1.683* (0.092)	_____
Miami	$P_2$	2.278** (0.023)	22.676*** (0.000)	_____	2.905*** (0.004)
New York	$P_1$	_____	85.501*** (0.000)	2.472** (0.013)	3.238*** (0.001)
	$P_2$	_____	6.238*** (0.000)	_____	_____
San Diego	$P_1$	_____	6.490*** (0.000)	_____	_____
	$P_2$	_____	_____	_____	_____

<sup>5</sup>Boston, Chicago, Denver, New York, San Diego, San Francisco.

<sup>6</sup> Boston, Chicago, Denver, New York, San Diego, San Francisco and Washington.

			4.719*** (0.000)		
Washington	$P_3$	1.717* (0.090)			
Aggregate housing returns	$P_1$	4.041*** (0.000)			
	$P_2$	3.333*** (0.000)			
REIT Returns	$P_1$			3.178*** (0.002)	
	$P_3$			3.664*** (0.000)	
S&P500 returns	$P_1$			6.027*** (0.000)	
	$P_2$		2.157** (0.031)	2.272** (0.023)	
	$P_3$			3.211*** (0.001)	

Notes:  $P_1$  = full sample period;  $P_2$  = conventional monetary policy period and  $P_3$  =unconventional monetary policy period.

GJR-GARCH(1,1) specification used: *Mean equation:*  $R_t = \mu + \rho R_{t-1} + \gamma_0 MP_{t-1} + \gamma_1 MS_{t-1} + \varepsilon_t$ .

*Volatility equation:*  $h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \varepsilon_{t-1}^2 d_{t-1} + \beta_0 h_{t-1} + d_1 MP_{t-1} + d_2 MS_{t-1}$ . The standard errors are given in parenthesis. Level of significance: \*\*\*1 percent; \*\* 5 percent, \*10 percent.

### Panel B: Negative Effects

Metropolitan Area	Sample period	Monetary policy surprise		Macroeconomic surprise	
		Returns	Volatility	Returns	Volatility
Boston	$P_1$		-3.676*** (0.000)		
	$P_2$		-3.973*** (0.000)		
Las Vegas	$P_1$		-3.331*** (0.000)		
	$P_2$		-2.063**		
	$P_3$		(0.039)		
Los Angeles	$P_2$		-1.650* (0.099)		
	$P_2$		-1.721* (0.085)		
Miami	$P_1$		-2.018** (0.044)		-3.218*** (0.001)
New York	$P_1$		-1.993** (0.046)		
	$P_2$		-1.925* (0.054)		
Washington	$P_2$		-5.368*** (0.000)	-1.908* (0.056)	
	$P_1$		-5.221*** (0.000)		

Aggregate Returns	$P_2$	_____	-1.828*	_____	_____
			(0.068)		
REIT Returns	$P_1$	-1.747*			-13.763***
		(0.081)			(0.000)
	$P_3$	-2.186**			
		(0.029)			
S&P500 Returns	$P_1$	-3.435***	_____	_____	-2928.55***
		(0.001)			(0.000)
	$P_2$	-2.243**	_____	_____	-5.810***
		(0.025)			(0.000)
	$P_3$	_____	_____	_____	-1.983**
					(0.047)

Notes:  $P_1$  = full sample period;  $P_2$  = conventional monetary policy period and  $P_3$  =unconventional monetary policy period. GJR-GARCH(1,1) specification used: *Mean equation:*  $R_t = \mu + \rho R_{t-1} + \gamma_0 MP_{t-1} + \gamma_1 MS_{t-1} + \varepsilon_t$ . *Volatility equation:*  $h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \varepsilon_{t-1}^2 d_{t-1} + \beta_0 h_{t-1} + d_1 MP_{t-1} + d_2 MS_{t-1}$ . The standard errors are given in parenthesis. Level of significance: \*\*\*1 percent; \*\* 5 percent, \*10 percent.

The full sample results for the impact of macroeconomic surprises on housing returns at the MSA level shows that macroeconomic surprises do not statistically impact housing returns for most of the MSAs, with the exception of Los Angeles and New York which show a positive and significant impact at a 10 percent level of significance. For the conventional monetary policy period, macroeconomic surprises have a negative and statistically significant (10% level) impact on housing returns for Washington only, and the rest are insignificant. The results show that macroeconomic surprises do not statistically impact housing returns for all MSAs, for the period of the unconventional monetary policy.

The estimated parameter of the lagged conditional variance ( $\alpha_2$ ) is positive and statistically significant for Miami, New York, San Francisco and Washington for the full sample period, Boston during the conventional and unconventional monetary policy period and aggregate returns as well as S&P500 returns for all three periods. The positive coefficient  $\alpha_2$  implies that bad news increases volatility more than good news ( $\alpha_1$ ). This means that policy shocks have an asymmetric impact on conditional variance for these MSAs. The results show that monetary policy surprises have a negative and statistically significant impact on housing returns volatility at a 5 percent level of significance for Boston, Miami and Washington for the full sample period, while it has a positive and statistically significant impact for Denver and New York. For the conventional monetary policy period, the policy

surprises have a negative and statistically significant impact on housing return volatility for Boston, Los Angeles and Washington, with Miami, New York, San Diego showing a positive and statistically significant impact. In the unconventional monetary policy period, monetary policy surprises have a mostly positive but insignificant impact on housing returns volatility.

With regards to the effect of macroeconomic surprises on the volatility of housing returns, the results show a positive and statistically significant impact at a 1% level for Denver, but negative and statistically significant for Miami and New York for the full sample. For the conventional monetary policy period, macroeconomic surprises have a positive and statistically significant effect on housing returns volatility for Denver and Miami at a 1% level of significance. In the case of New York, the macroeconomic surprises have a negative impact on housing returns volatility, but only at a 10% level of significance.

For the aggregate housing market, results indicate that monetary policy surprises have a positive and statistically significant impact on housing returns for the full sample period and conventional monetary policy period. For the unconventional monetary policy period, monetary policy surprises have an insignificant impact on housing returns. Macroeconomic surprises have no significant impact on aggregate housing returns across all sample periods.

The estimated parameter of the lagged conditional variance is positive and statistically significant, which suggests that volatility will increase more following a negative return shock and confirms volatility asymmetry for daily aggregate housing returns. This is in line with results Wang (2014). At an aggregate level, monetary policy surprises have a negative and statistically impact (10% level of significance) on daily aggregate housing returns during the conventional monetary policy period only.

For comparison, we also evaluate the impact of monetary policy and macroeconomic surprises on REIT and S&P500 returns and volatility. Results show that monetary policy surprises negatively impact REIT returns for the full sample and unconventional monetary

policy period, but does not impact the volatility of REIT returns for all the periods. However, during the conventional monetary policy period, monetary policy surprises have an insignificant impact on REIT. This corroborates the findings of Claus et al., (2014) who show that REIT prices have an insignificant response to monetary policy shocks during normal monetary policy settings, but significant during the zero lower bound period. Macroeconomic surprises have a positive and statistically significant impact on REIT returns during the full sample and conventional monetary policy period, but a negative and significant impact on REIT volatility during the full sample period. Volatility asymmetry exists, similar to the aggregate housing market. Wang (2014) obtains similar results. In terms of the S&P500 returns, results show that monetary policy surprises have a negative and statistically significant (5% level) impact on stock returns during the full sample and conventional monetary policy period. However, macroeconomic surprises show a positive and statistically significant impact on stock returns during the conventional and unconventional monetary policy periods. Similar to the aggregate housing market, the stock market also shows evidence of volatility asymmetry. The results show that monetary policy surprises have a positive and significant impact on stock returns volatility during the conventional monetary policy period. However, the macroeconomic surprise has a negative and statistically significant impact on stock returns volatility for all the sample periods.

Overall, evidence suggests that monetary policy surprises, rather than macroeconomic news surprises, generally have a more significant impact on housing returns, especially volatility. In some MSAs, the volatility is increasing as in the case of Chicago, Denver, Miami (full sample period), New York and San Diego and in some cases decreasing as in the case of Boston, Las Vegas, Los Angeles, Miami (unconventional monetary policy period) and Washington. The results show that mostly coastal MSAs exhibit lower return volatility compared to the most inland MSAs which showed an increase in volatility. Although there

are a few exceptions, in general, monetary policy surprises affect housing returns volatility more during the conventional monetary policy period. The fact that monetary policy surprises are more important at higher frequency than macroeconomic news surprises is an indication that agents put more weight on monetary policy movements at the shorter-run. This is possibly also a reason we see more impact on volatility, i.e., the risk-profile of the housing market, than returns, which are likely to be affected by such decisions in the longer-term. Finally, the increase in volatility of the inland MSAs, could be due to them being global cities, and tends to behave just like equities.

#### **4. Conclusion**

In this paper, we employ a GJR-GARCH model to analyze the impact of monetary policy and macroeconomic surprises on daily housing returns and volatility for 10 U.S MSAs and on aggregate housing returns. We further compare the results with the impact on the aggregate stock market using S&P500 returns. We use a set of newly constructed daily housing price series, which allows us to investigate the volatility asymmetries and volatility relationship of the housing market and monetary policy and macroeconomic surprises.

The evidence suggests that at the MSAs level, monetary policy surprises have a positive and significant impact on housing returns for Denver and Miami during the period of conventional monetary policy and for Washington during the unconventional monetary policy period. Furthermore, monetary policy surprises have a positive and significant impact on housing volatility for the full sample period for Denver, New York and San Francisco, and then for Chicago, Miami and New York and San Diego as well during the conventional monetary policy period. During the unconventional monetary policy period, the policy surprises have a positive impact on Washington only. At an aggregate level, monetary policy surprises have a positive impact on housing returns during the full sample and conventional monetary policy period. This is in contrast to the aggregate stock market where we find a

significant response of market returns in all three periods and the volatility response only in and the conventional monetary policy period.

In terms of macroeconomic surprises, the results suggest that they have a positive and significant impact on housing returns during the full sample period for Los Angeles and New York. Macroeconomic surprises have a positive impact on housing volatility in Las Vegas and Miami during the conventional monetary policy period and unconventional monetary policy period for Las Vegas only.

The results show that monetary policy has a negative and significant impact mostly on housing volatility across the various periods for Boston, Las Vegas, Los Angeles, Miami, New York and Washington. On aggregate, results show that monetary policy surprises have a negative and statistically significant impact on housing returns volatility during the conventional monetary policy period compared to the stock market where it shows an impact on stock returns during the full sample and conventional.

The evidence suggests that macroeconomic surprises do not have a negative and statistically significant impact on housing returns both at the MSA and aggregate level. However, in terms of volatility, macroeconomic surprises have a negative and statistically significant impact for Miami only during the full sample period. At the aggregate level, macroeconomic surprises show a negative and significant impact on the stock market during the full sample, unconventional and conventional monetary policy period.

Overall, at the MSA level monetary policy and macroeconomic surprises do not have a significant impact on housing returns for most MSAs for the full sample, conventional and unconventional monetary policy period. However, the results show that in relation to volatility, monetary policy surprises have a significant impact on housing returns volatility for 5 MSAs in the full sample, 5 in the conventional monetary policy period, but a mostly positive and insignificant impact in the unconventional monetary policy period.

Macroeconomic surprises largely have an insignificant impact on housing returns volatility across all sample periods and most MSAs.

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## Appendix

**Table A1: Summary statistics for the 10 U.S MSA and aggregate housing returns**

Housing returns	Sample Period	Observations	Minimum	Maximum	Average	Standard Deviation	Skewness	Kurtosis	Jarque-Bera ( <i>p</i> -value)
Boston	1/6/1995 - 10/11/2012	4424	-5.419	2.947	0.017	0.400	-1.119	18.344	0.000
Chicago	9/7/1999-10/12/2012	3265	-5.300	7.081	0.001	0.593	0.131	13.417	0.000
Denver	5/6/1999 – 10/17/2012	3344	-4.434	2.930	0.010	0.330	-0.823	20.027	0.000
Las Vegas	1/6/1995 – 10/17/2012	4399	-8.667	5.425	0.001	0.569	-1.613	28.151	0.000
Los Angeles	1/6/1995–10/23/2012	4425	-3.030	1.602	0.017	0.381	-0.510	6.015	0.000
Miami	4/6/1998-10/15/2012	3587	-3.073	4.261	0.013	0.505	0.085	6.950	0.000
New York	1/6/1995-10/23/2012	4442	-5.162	3.988	0.017	0.380	-0.041	19.232	0.000
San Diego	1/5/1996-10/23/2012	4163	-2.478	2.082	0.022	0.411	-0.179	4.916	0.000
San Francisco	1/6/1995-10/18/2012	4422	-4.403	3.855	0.016	0.530	-0.955	9.036	0.000
Washington	6/6/2001-10/23/2012	2816	-4.477	2.650	0.015	0.506	-0.192	6.825	0.000
Aggregate housing returns	6/6/2001-10/11/2012	2806	-0.627	0.663	0.010	0.163	-0.211	3.770	0.000
REITs returns	6/6/2001-10/11/2012	2806	-21.945	17.124	0.019	2.222	-0.185	17.863	0.000
S&P500 returns	6/6/2001-10/11/2012	2806	-9.470	10.246	0.004	1.331	-0.360	10.148	0.000
Monetary policy surprise	1/6/1995-10/11/2012	4424	-0.413	0.125	-0.000	0.013	-18.355	510.165	0.000
Macroeconomic surprise	1/6/1995-10/11/2012	4424	-1.649	2.451	0.000	0.139	0.373	52.795	0.000

**Note:** The Jarque-Bera test has the null hypothesis of normality.

**Table A2: GJR-GARCH model estimation results of the impact of monetary policy and macroeconomic surprises on housing returns and volatility for 10 US metropolitan statistical areas and the aggregate housing returns**

Metropolitan Area		Full sample			Conventional monetary policy period			Unconventional monetary policy period			
		Coefficient	<i>z</i> -Statistic	<i>p</i> -value	Coefficient	<i>z</i> -Statistic	<i>p</i> -value	Coefficient	<i>z</i> -Statistic	<i>p</i> -value	
Boston	Mean	$\gamma_0$	-0.105	-0.197	0.844	-0.164	-0.315	0.753	3.796	0.399	0.690
		$\gamma_1$	0.038	0.819	0.413	0.034	0.652	0.514	0.054	0.516	0.606
	Volatility	$\alpha_0$	0.000	6.973***	0.000	0.002	7.675***	0.000	0.007	5.099***	0.000
		$\alpha_1$	0.148	3.558***	0.000	0.012	3.043***	0.002	0.055	2.463**	0.014
		$\alpha_2$	0.049	1.183	0.237	0.035	5.733***	0.000	0.080	2.496**	0.013
		$\beta_0$	0.949	276.741***	0.000	0.955	279.981***	0.000	0.871	45.828***	0.000
		$d_1$	-0.254	-3.676***	0.000	-0.250	-3.937***	0.000	-0.020	-0.019	0.985
$d_2$	0.002	0.313	0.754	0.005	1.080	0.280	0.007	0.408	0.684		
Chicago	Mean	$\gamma_0$	-0.365	-0.433	0.665	-0.503	-0.911	0.362	6.434	0.228	0.820

		$\gamma_1$	-0.092	-1.553	0.120	-0.080	-0.564	0.573	0.052	0.182	0.855
	Volatility	$\alpha_0$	0.000	4.311***	0.000	0.171	3.297***	0.001	0.447	1.070	0.285
		$\alpha_1$	0.139	2.536**	0.011	0.057	2.650***	0.008	-0.009	-0.443	0.658
		$\alpha_2$	0.046	0.910	0.363	-0.045	-1.600	0.110	0.034	0.796	0.426
		$\beta_0$	0.948	254.890***	0.000	0.508	3.529***	0.000	0.465	0.928	0.354
		$d_1$	-0.021	-0.224	0.823	0.844	2.500**	0.012	5.184	1.626	0.104
		$d_2$	-0.003	-0.306	0.759	-0.009	-0.116	0.908	-0.198	-0.481	0.631
Denver	Mean	$\gamma_0$	-0.006	-0.056	0.956	-0.135	-0.190	0.849	0.822	0.028	0.977
		$\gamma_1$	0.028	0.474	0.635	0.088	2.589**	0.010	-0.020	-0.151	0.880
	Volatility	$\alpha_0$	0.000	3.714***	0.000	0.003	7.999***	0.000	0.111	1.462	0.144
		$\alpha_1$	0.150	3.038***	0.002	0.072	9.978***	0.000	0.041	0.436	0.663
		$\alpha_2$	0.050	0.703	0.482	-0.031	-4.418***	0.000	-0.027	-0.286	0.775
		$\beta_0$	0.528	3.906***	0.000	0.916	114.012* **	0.000	0.528	1.657*	0.098
$d_1$	0.502	16.023***	0.000	-0.058	-1.046	0.296	2.311	1.212	0.225		
$d_2$	0.082	5.125***	0.000	0.013	4.025***	0.000	0.175	2.745***	0.006		
Las Vegas	Mean	$\gamma_0$	0.435	0.621	0.534	0.525	0.796	0.426	0.836	0.078	0.938
		$\gamma_1$	-0.027	-0.600	0.549	-0.015	-0.314	0.754	-0.013	-0.136	0.892
	Volatility	$\alpha_0$	0.000	4.204***	0.000	0.000	3.344***	0.001	0.201	4.543***	0.000
		$\alpha_1$	0.012	6.661***	0.000	0.013	5.646***	0.000	-0.024	-0.907	0.364
		$\alpha_2$	0.001	1.049	0.294	0.001	0.861	0.389	0.018	0.504	0.614
		$\beta_0$	0.986	964.517***	0.000	0.985	803.190* **	0.000	-0.085	-0.374	0.709
$d_1$	-0.148	-3.331***	0.000	-0.100	-2.063**	0.039	-8.078	-1.650*	0.099		
$d_2$	0.007	1.277	0.202	0.011	1.777*	0.076	0.158	3.336***	0.001		
Los Angeles	Mean	$\gamma_0$	0.159	0.456	0.648	0.046	0.121	0.904	5.581	0.545	0.585
		$\gamma_1$	0.056	1.683*	0.092	0.055	1.598	0.110	0.108	0.811	0.417
	Volatility	$\alpha_0$	0.000	4.731***	0.000	0.001	4.855***	0.000	0.114	0.915	0.360
		$\alpha_1$	0.013	3.150***	0.002	0.010	2.509**	0.012	0.002	0.030	0.976
		$\alpha_2$	0.027	5.200***	0.000	0.023	4.112***	0.000	0.076	1.297	0.195
		$\beta_0$	0.966	308.731***	0.000	0.969	265.843* **	0.000	0.432	0.729	0.466
$d_1$	-0.069	-1.223	0.221	-0.094	-1.721*	0.085	1.270	0.431	0.667		
$d_2$	0.006	1.267	0.205	0.007	1.480	0.139	-0.041	-0.473	0.636		
Miami	Mean	$\gamma_0$	0.466	0.939	0.347	0.547	2.278**	0.023	4.835	0.782	0.434
		$\gamma_1$	0.015	0.279	0.780	0.012	0.150	0.881	-0.007	-0.045	0.965
	Volatility	$\alpha_0$	0.000	6.317***	0.000	0.127	22.525** *	0.000	0.187	0.745	0.456
		$\alpha_1$	0.144	0.498	0.618	0.155	5.198***	0.000	0.021	0.403	0.687
		$\alpha_2$	0.047	6.332***	0.000	-0.014	-0.357	0.721	-0.02	-0.436	0.663
		$\beta_0$	0.985	488.550***	0.000	0.455	213.733* **	0.000	0.364	0.434	0.665
$d_1$	-0.091	-2.018**	0.044	0.617	22.676** *	0.000	1.885	0.267	0.789		
$d_2$	-0.018	-3.218***	0.001	0.157	2.905***	0.004	-0.087	-0.740	0.459		
New York	Mean	$\gamma_0$	-0.506	-0.638	0.523	-0.165	-0.247	0.805	0.768	0.185	0.853
		$\gamma_1$	0.113	1.651*	0.099	0.078	0.929	0.353	0.052	0.486	0.627
	Volatility	$\alpha_0$	0.000	14.041***	0.000	0.112	9.212***	0.000	0.081	1.587	0.113
		$\alpha_1$	0.148	5.448***	0.000	0.097	3.445***	0.001	0.021	0.470	0.638
		$\alpha_2$	0.049	1.853*	0.064	-0.005	-0.191	0.848	-0.094	-2.129**	0.033
		$\beta_0$	0.533	10.327***	0.000	0.539	12.681** *	0.000	0.479	1.395	0.163
$d_1$	0.512	14.382***	0.000	0.556	6.238***	0.000	1.062	0.263	0.793		
$d_2$	-0.068	-1.993**	0.046	-0.082	-1.925*	0.054	0.017	0.351	0.726		
San Diego	Mean	$\gamma_0$	-0.308	-0.603	0.546	-0.301	-0.578	0.563	2.760	0.136	0.892
		$\gamma_1$	0.042	0.598	0.549	0.023	0.293	0.769	0.016	0.078	0.937
	Volatility	$\alpha_0$	0.000	4.232***	0.000	0.114	4.377***	0.000	0.144	2.076**	0.038
		$\alpha_1$	0.145	2.835***	0.005	0.028	0.817	0.414	0.017	0.341	0.733
		$\alpha_2$	0.046	0.775	0.438	-0.039	-1.104	0.270	-0.087	-1.629	0.103
		$\beta_0$	0.496	4.509***	0.000	0.472	3.706***	0.000	0.460	1.683*	0.092
$d_1$	0.608	6.490***	0.000	0.524	4.719***	0.000	1.771	0.482	0.630		
$d_2$	-0.009	-0.243	0.808	-0.004	-0.105	0.917	-0.011	-0.088	0.930		
San Francisc	Mean	$\gamma_0$	-0.635	-1.471	0.141	-0.628	-1.229	0.219	-6.044	-0.120	0.905
		$\gamma_1$	-0.020	-0.169	0.866	-0.006	-0.045	0.964	-0.050	-0.178	0.859

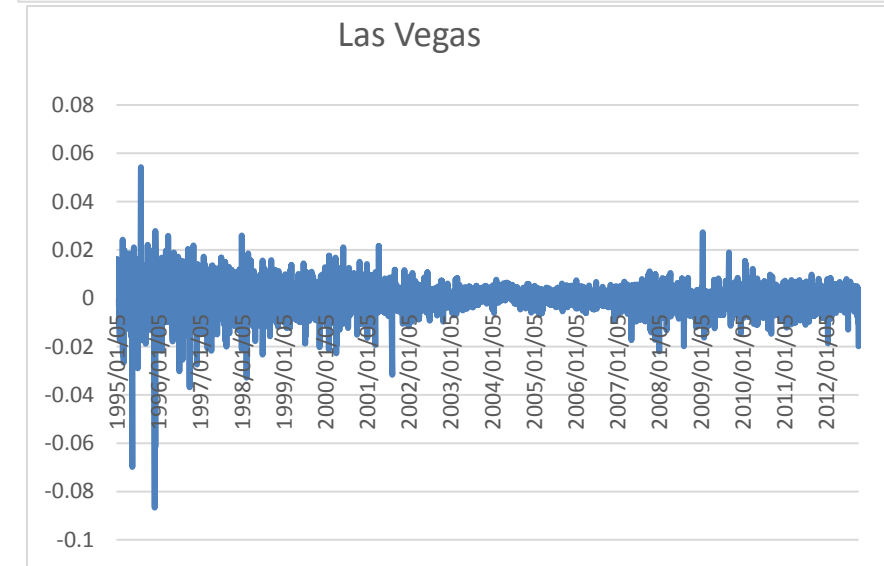
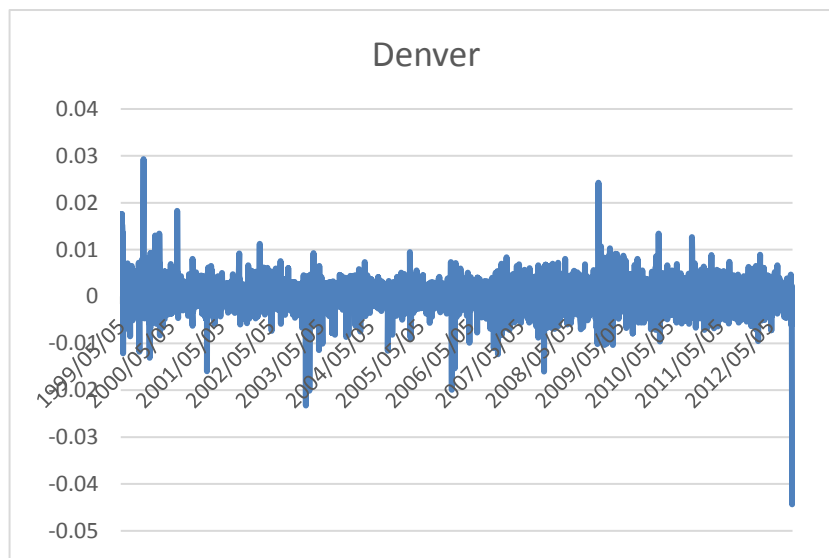
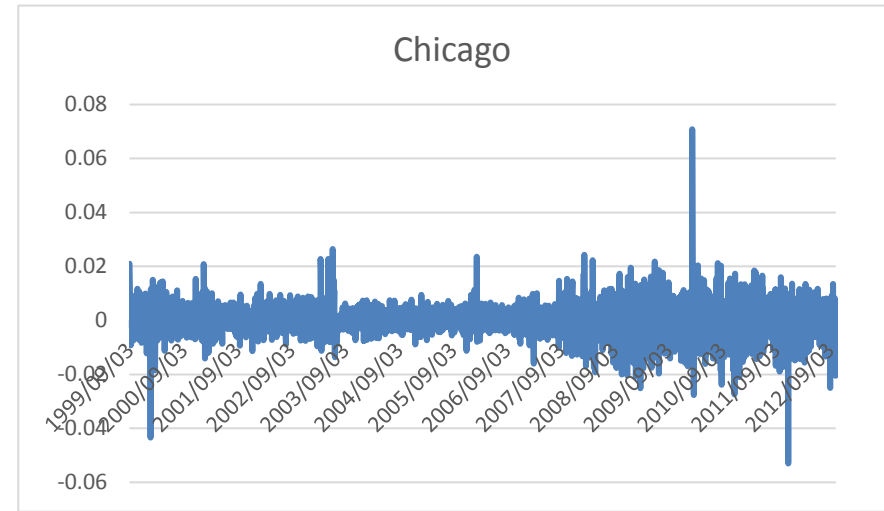
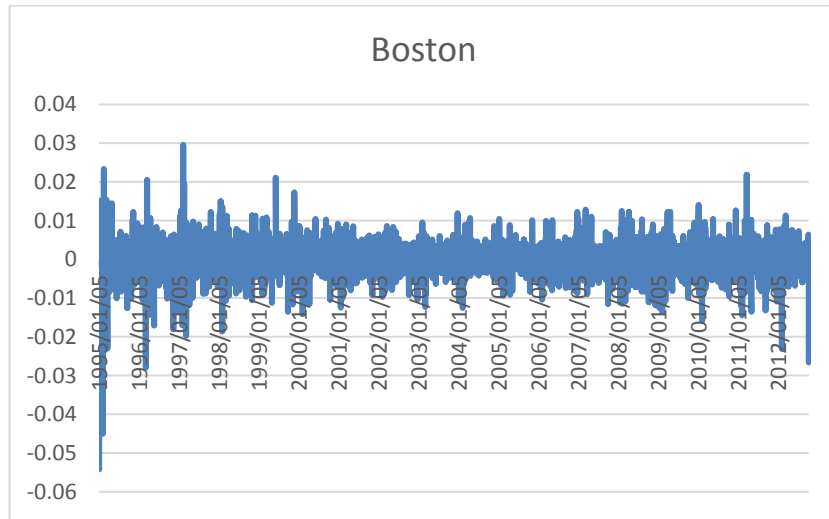
o	Volatility	$\alpha_0$	0.000	6.149***	0.000	0.197	39.966** *	0.000	0.344	2.171**	0.030
		$\alpha_1$	0.012	5.446***	0.000	0.049	1.474	0.141	0.006	0.068	0.945
		$\alpha_2$	0.013	4.185***	0.000	-0.057	-1.697	0.090	-0.113	-1.406	0.160
		$\beta_0$	0.512	557.713***	0.000	0.530	173.892* **	0.000	0.530	2.256**	0.024
		$d_1$	1.094	1.525	0.127	1.008	1.487	0.137	2.772	0.532	0.595
		$d_2$	-0.028	-0.406	0.685	-0.026	-0.373	0.709	-0.054	-0.189	0.850
Washing ton	Mean	$\gamma_0$	0.003	0.002	0.998	-0.235	-0.166	0.869	0.983	1.717*	0.09
		$\gamma_1$	-0.062	-0.998	0.318	-0.136	-1.908*	0.056	0.195	1.445	0.149
	Volatility	$\alpha_0$	0.000	5.275***	0.000	0.001	4.179***	0.000	0.101	1.638	0.102
		$\alpha_1$	0.033	0.895	0.371	0.030	3.836***	0.000	0.084	2.127**	0.034
		$\alpha_2$	0.007	203.129***	0.000	0.016	1.613	0.107	-0.026	-0.582	0.560
		$\beta_0$	0.958	203.181***	0.000	0.955	162.503* **	0.000	0.579	2.506**	0.012
$d_1$	-0.684	-5.221***	0.000	-0.691	-5.368***	0.000	1.691	0.743	0.458		
$d_2$	0.006	0.557	0.577	0.005	0.418	0.676	-0.067	-0.719	0.472		
Aggregat e housing returns	Mean	$\gamma_0$	0.937	4.041***	0.000	0.791	3.333***	0.001	4.197	0.868	0.385
		$\gamma_1$	-0.006	-0.256	0.798	-0.023	-0.896	0.370	0.057	1.094	0.274
	Volatility	$\alpha_0$	0.000	4.630***	0.000	0.000	2.317**	0.021	0.000	2.852***	0.004
		$\alpha_1$	0.000	0.000	0.999	-0.000	-0.350	0.726	-0.023	- 9.167***	0.000
		$\alpha_2$	0.016	4.899***	0.000	0.012	3.679***	0.000	0.029	5.248***	0.000
		$\beta_0$	0.985	275.219***	0.000	0.991	242.318* **	0.000	0.999	289.440* **	0.000
$d_1$	-0.020	-1.578	0.115	-0.019	-1.828	0.068*	0.019	0.272	0.786		
$d_2$	0.002	1.536	0.125	0.001	1.205	0.228	0.003	0.741	0.459		
REITs Returns	Mean	$\gamma_0$	-0.060	-1.747**	0.081	-3.653	-1.399	0.162	-57.822	-2.186**	0.029
		$\gamma_1$	0.005	3.178***	0.002	-0.031	-0.201	0.841	1.086	3.664***	0.000
	Volatility	$\alpha_0$	0.000	16.311***	0.000	0.021	3.988***	0.000	0.028	2.295**	0.022
		$\alpha_1$	0.237	9.380***	0.000	0.079	4.478***	0.000	0.091	3.448***	0.001
		$\alpha_2$	0.154	4.002***	0.000	0.106	4.414***	0.000	0.051	1.850*	0.064
		$\beta_0$	0.442	20.043***	0.000	0.862	60.002** *	0.000	0.875	51.032** *	0.000
$d_1$	0.000	0.347	0.729	1.477	0.638	0.524	24.824	1.299	0.194		
$d_2$	-0.000	-13.373***	0.000	0.084	1.102	0.270	0.046	0.200	0.842		
S&P500	Mean	$\gamma_0$	-6.465	-2.540**	0.011	-5.999	-2.243**	0.025	-24.576	-1.494	0.135
		$\gamma_1$	0.520	3.641***	0.000	0.412	2.272**	0.023	0.729	3.211***	0.001
	Volatility	$\alpha_0$	0.000	14.959***	0.000	0.008	5.749***	0.000	0.024	5.020***	0.000
		$\alpha_1$	0.178	6.949***	0.000	-0.022	-2.779***	0.005	-0.033	-2.214**	0.027
		$\alpha_2$	0.159	4.869***	0.000	0.117	9.525***	0.000	0.196	7.762***	0.000
		$\beta_0$	0.934	121.592***	0.000	0.956	114.092* **	0.000	0.916	62.959** *	0.000
$d_1$	1.910	1.647	0.100	2.439	2.157**	0.031	5.948	0.793	0.428		
$d_2$	-0.222	-5.804***	0.000	-0.187	-5.810***	0.000	-0.207	-1.983**	0.047		

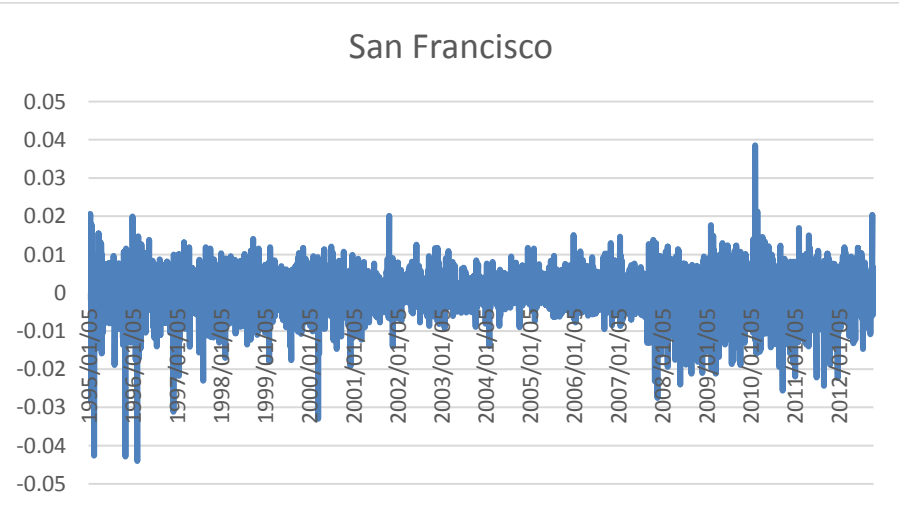
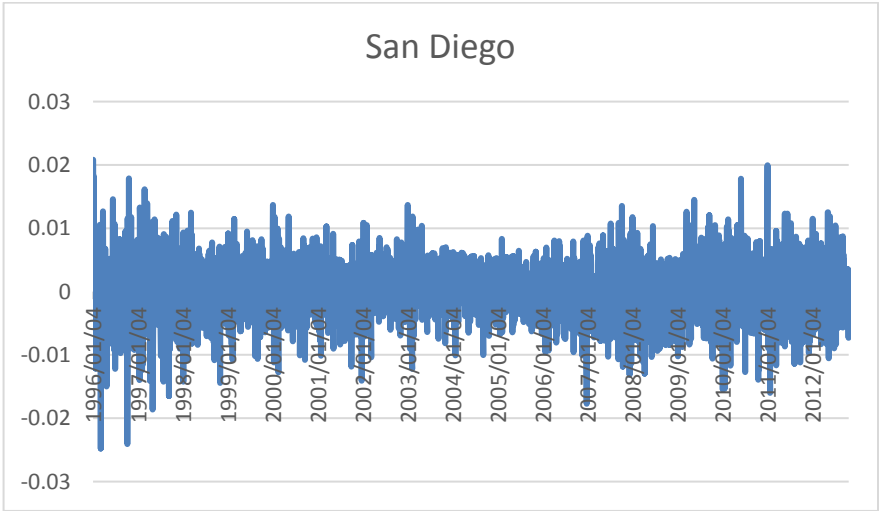
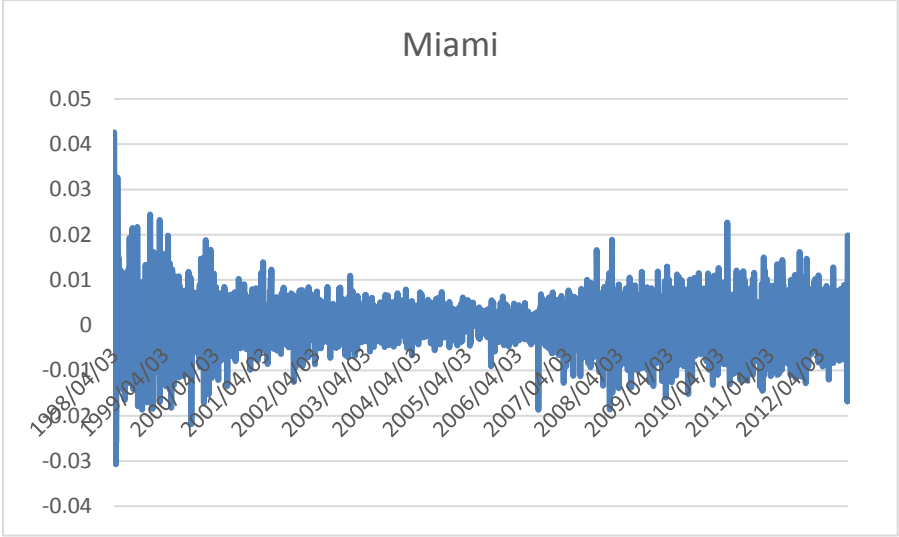
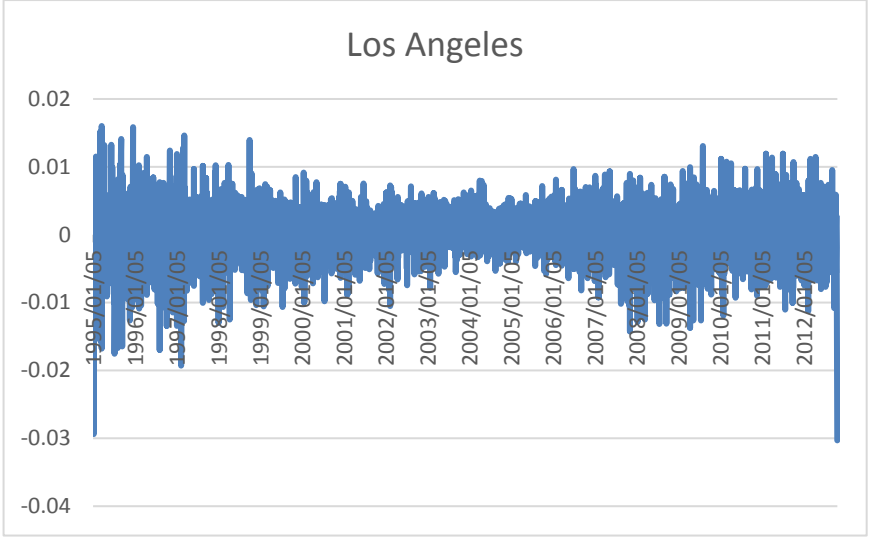
**Note:** GJR-GARCH(1,1) specification used: *Mean equation:*  $R_t = \mu + \rho R_{t-1} + \gamma_0 MP_{t-1} + \gamma_1 MS_{t-1} + \varepsilon_t$ .

*Volatility equation:*  $h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \varepsilon_{t-1}^2 d_{t-1} + \beta_0 h_{t-1} + d_1 MP_{t-1} + d_2 MS_{t-1}$ . MP is the monetary policy shock – Federal Funds Rate and the MS is the macroeconomic shock.

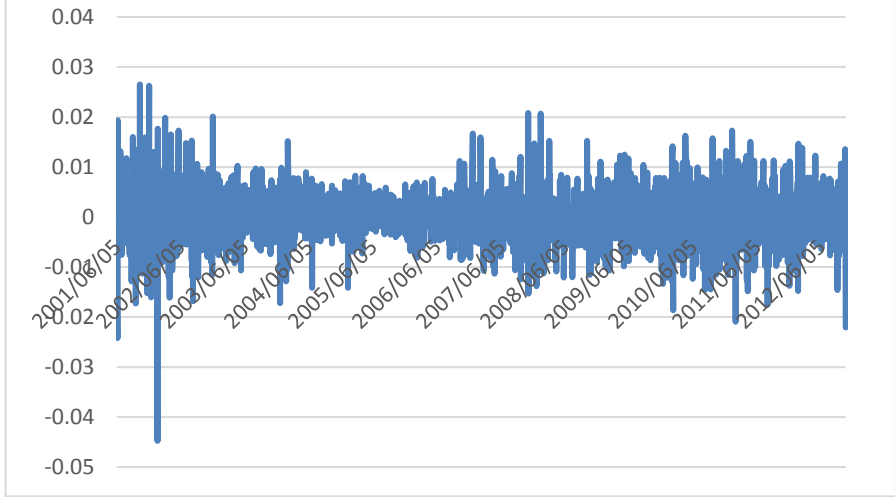
Level of significance: \*\*\*1 percent; \*\* 5 percent, \*10 percent.

**Figure A1: Daily housing returns for 10 U.S MSAs**

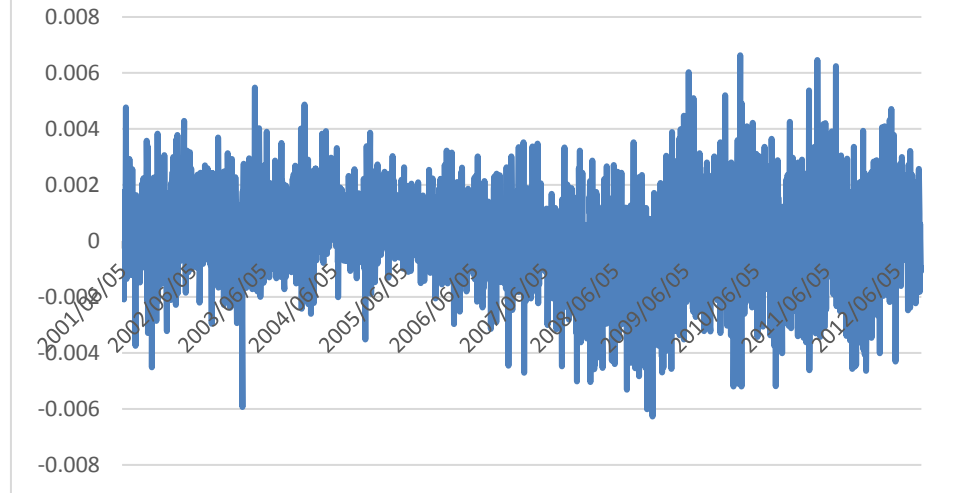




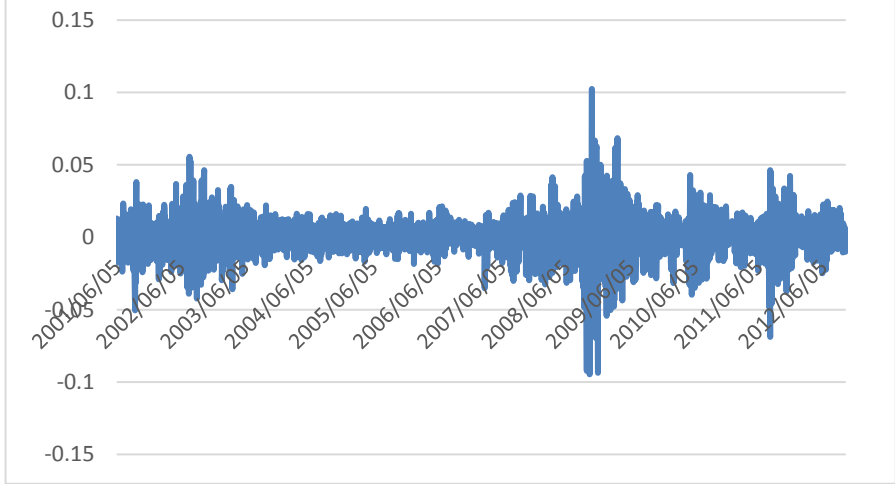
Washington



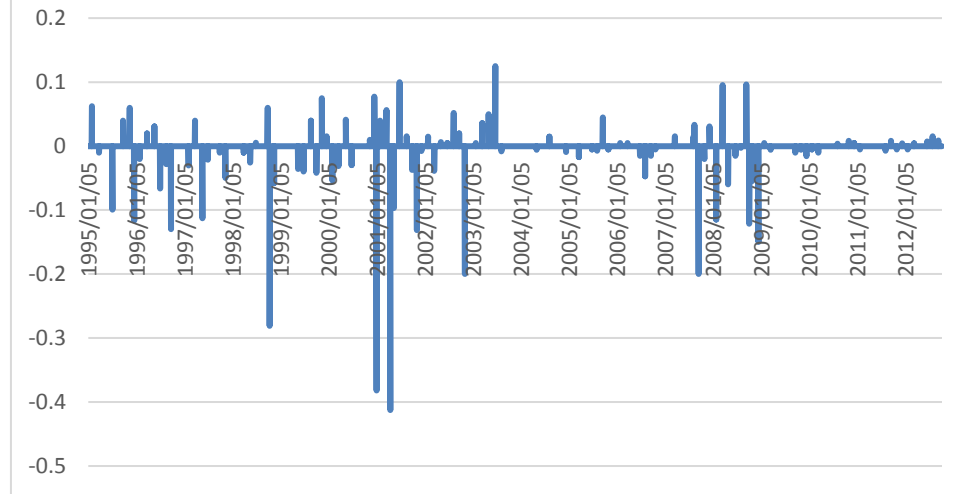
Aggregate housing returns



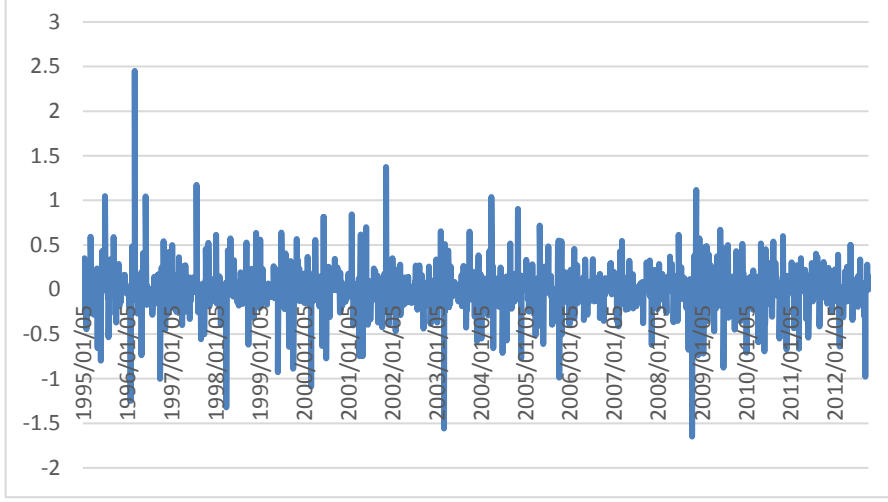
S&P500 returns



Monetary policy surprise



Macroeconomic surprise



REIT Returns

