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ARTICLE

The nonlinear effect of macroeconomic and financial uncertainty on regional housing prices in the USA

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Abstract

This study investigated the nonlinear effects of macroeconomic and financial uncertainty on regional housing prices in the USA. The sample data contain 50 largest metropolitan areas in the USA, and panel threshold regression was employed to test the nonlinear effects of macroeconomic and financial uncertainty. Regardless of using macroeconomic uncertainty or financial uncertainty as the threshold variable, the results of panel threshold regression confirm a nonlinear effect exists. Rising macroeconomic uncertainty, whether in the low or high regime, will reduce housing prices in most of the USA, but if macroeconomic risk reaches the high regime, the effect of macroeconomic uncertainty will be insignificant. Contrastingly, financial risk can have a positive effect on housing prices in the low and middle regimes of financial uncertainty, but this effect becomes negative in the high regime of financial uncertainty. These findings confirm that the responses of regional housing prices will differ if the macroeconomic and financial risk level is high.

Keywords Housing prices · Macroeconomic uncertainty · Financial uncertainty · Panel threshold regression

JEL Classification E32 · E44 · R21 · R30

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1 Introduction

The economic decisions taken by governments, firms, and households are influenced by economic uncertainty. Jurado et al. (2015) proved both macroeconomic and financial uncertainty play significant roles in the business cycle. Minsky (1980) theory linked the financial market fragility as the result of the speculative investment which lead to the excessive debt from borrower has explain the mechanism of subrime mortgage and financial crisis. Higher uncertainty leads to reduced consumer spending, production, and employment, and it also causes higher financial risk. As to the impact of economic uncertainty on the housing market, greater economic uncertainty can reduce housing supply, because real estate developers may postpone construction when facing higher uncertainty regarding housing demand or financing costs. On the other hand, housing demand will also drop due to reductions in the household consumption of durable goods in response to greater uncertainty regarding future employment, income and wealth. Hence, economic uncertainty will affect both housing supply and housing demand.

Further, as with other financial assets, housing is an important component of investment portfolios. Uncertainty reduces housing demand because housing is an irreversible form of investment, causing delays in decision made by the individual (Bernanke, 1983); an incomplete market and risk aversion will also cause uncertainty in housing investment (Craine, 1989). Conversely, El-Montasser et al. (2016) argue an increase in uncertainty could also increase housing demand and housing prices when the demand for other assets is more sensitive to uncertainty. Hence, uncertainty becomes a positive feature when risk aversion and incomplete market conditions are absent. Caballero (1991) and Abel and Eberly (1999) showed the effects of economic uncertainty on investment are not always negative, and depend on the degree of competition and the relative sizes of certain parameters. However, the impact of economic uncertainty on housing prices remains questionable, and likely depends on variations in place and time (Christou et al., 2019).

The relationship between housing prices and uncertainty has recently been studied empirically (Aye, 2018; Chien & Setyowati, 2020; Christou et al., 2017, 2019; Dorofeenko et al., 2014; El-Montasser et al., 2016), but few studies have addressed the effect of economic uncertainty on geographical regional housing markets. Actually, regional housing data vary idiosyncratically, and thus offer more detail regarding the housing market than national data. Since the additional information available in regional data can improve the accuracy of estimations of the effects of certain determinants on house prices, some recent papers have applied regional housing variables to examine the effects of economic uncertainty. Most of these applied the observable measures of economic uncertainty[1]—economic policy uncertainty (EPU), which is based on economic news published in newspapers (Baker et al. (2016)). For example, Choudhry (2020) explored the effect of EPU on 10 sets of regional house prices in England and Wales, showing EPU has a negative impact on regional housing prices. Bahmani-Oskooee and Ghodsi (2017) and Christidou and Fountas (2017) studied geographical housing prices in the USA to determine the effect of EPU.

[1] Bakas and Triantafyllou (2018) highlighted two different approaches to the measurement of economic uncertainty in the literature: observable and unobservable uncertainty measures. The former is based on the time series variations in observable economic variables, such as EPU (Baker et al., 2016). The latter is based on the empirical method of Jurado et al. (2015); here, it must be noted unobservable uncertainty cannot be measured by observed fluctuations in different economic variables, because these variables could change for reasons unrelated to uncertainty.

Contrastingly, Strobel et al. (2020) employed the unobservable measures included in the macroeconomic uncertainty index of Jurado et al. (2015), which is calculated based on the volatility of the unforecastable component of a large group of economic indicators. Using the dataset of US regional housing prices, Strobel et al. (2020) found macroeconomic uncertainty can significantly affect regional housing markets in the USA.

The aim of this paper is to determine the nonlinear relationship between economic uncertainty and regional housing prices based on a dataset of housing prices in US metropolitan areas. Following the line of Choudhry (2020) and Bahmani-Oskooee and Ghodsi (2017), this paper establishes a housing price model including economic uncertainty, but we focus on the effects derived from the economic uncertainty index (Jurado et al., 2015; JLN hereafter), not the EPU, on regional housing markets. The equilibrium models of Di Pasquale and Wheaton (1994) and Adams and Füss (2010) are used as the main theoretical framework for our housing model, to which two JLN economic uncertainty indices—macroeconomic uncertainty and financial uncertainty—are added.

The contributions of this paper are as follows: First, reviewing the literature, although some empirical studies have examined the effect of economic uncertainty on regional housing prices, most applied the observable measures of economic uncertainty—economic policy uncertainty (EPU), no studies explored how the unobservable measures of JLN financial uncertainty impact regional housing prices.[2] Given housing, a financial asset, is an important constituent of investment portfolios, financial uncertainty will cause investors to alter their *portfolio* allocation, which will further impact the housing market. As such, we apply the JLN indices to explore the effects of both macroeconomic and financial uncertainty on regional housing prices in the USA, and then compare the differences between the effects of these two kinds of uncertainty. Based on the empirical results, we find the effect of macroeconomic uncertainty on regional housing prices is negative but financial uncertainty has the opposite effect for most cases in both linear and nonlinear models.

Further, the existence of lumpy transaction costs in the housing market can have important threshold effects in a house market's aggregate demand (Kim and Bhattacharya, 2009), which can cause different housing price responses at various levels of economic uncertainty. However, there is almost no empirical research examining the threshold effects of economic uncertainty on regional housing prices. To explore the nonlinear effect of lower and higher levels of macroeconomic and financial uncertainty on regional housing prices in the USA, this paper employs the panel threshold regression of Hansen (1999) to fill the gap in the literature.

The rest of this study is structured as follows. Section 2 presents the literature review. Section 3 concerns model specification and methodology. Section 4 contains the discussion of the empirical results. Finally, Sect. 5 gives the conclusions.

2 Literature review

Many empirical studies have investigated the relationship between housing prices and important macroeconomic variables (McCarthy & Peach, 2004; Adams and Füss, 2010; Jinjarak & Sheffrin, 2011; Gupta et al., 2019, among others). Considering the importance

[2] The exception is represented by Strobel et al. (2020), who also applied the economic uncertainty indices of JLN, but they only discussed the impact of macroeconomic uncertainty.

of the linkage between the housing market and macroeconomic variables, the number of empirical studies investigating the importance of economic uncertainty for the housing market is growing. Most existing empirical studies focus on how EPU affects housing market variables. For example, El-Montasser et al. (2016) studied the causality between EPU and housing prices in seven developed countries via a bootstrap panel causality test, finding bi-directional causality in France and Spain, but only unidirectional causality for the remaining countries.

Aye (2018) analyzed the causality between EPU and housing returns using cross-sample validation Granger causality in eight emerging economies. The identified linear causality confirmed that EPU only causes real housing returns in Chile and China, but the presence of time-varying causality confirmed that EPU can determine housing returns in all countries except India. Christou et al. (2017) employed EPU for the out-of-sample forecasting of real housing returns in 11 OECD countries, applying time series and panel vector autoregressive models, and their empirical results show that EPU can help forecast real housing returns. Balcilar et al. (2021) also examined the dynamic relationship between real housing price return and EPU using the panel data of 16 countries. Their empirical results show that a positive EPU shock will reduce housing prices, and there is strong and robust Granger causality between EPU and housing prices.

As opposed to the above studies, which only focus on the linkage between EPU and housing markets, other empirical works have employed other uncertainty variables. Dorofeenko et al. (2014) estimated time-varying uncertainty by employing firm-level productivity data for the USA, proving that uncertainty in the housing production sector is an impulse mechanism that is quantitatively important to understanding housing price changes. Christou et al. (2019) estimated macroeconomic uncertainty based on a comprehensive time series dataset with real economic activity, price, and financial variables, finding that the shock of macroeconomic uncertainty negatively impacts the housing variables (sales, prices, permits, and starts) via the time-varying parameter factor augmented vector autoregression model. Chien and Setyowati (2020) established a model of housing price instability containing four uncertainty variables—EPU, geopolitical risk index, macroeconomic uncertainty, and financial uncertainty—to investigate the impacts of economic and political risks on the housing market. Based on panel data for 56 countries from 2001Q1 to 2018Q2, they found that macroeconomic uncertainty and EPU positively affect house price instability, while financial uncertainty and geopolitical risk have a negative effect.

Considering that regional housing data vary idiosyncratically and thus contain more housing market information than national data, some papers apply regional housing variables to examine the effect of economic uncertainty. Choudhry (2020) indicate that the additional information content in regional data can be helpful in obtaining more accurate estimates of the effect of the determinants on house prices. Hence, he employs the bounds cointegration test to explore the effect of EPU on 10 regional house prices of England and Wales, and the results indicate, no matter in the long run or in the short run, there is a negative effect of EPU on regional housing prices. Bahmani-Oskooee and Ghodsi (2017) focus on the effect of EPU on regional housing prices in 50 US states and Washington, DC. They use the bounds test cointegration and find that EPU causes significant short-run effects in 24 states, the long-run effects only in 17 states. Christidou and Fountas (2017) also employ EPU and the state data in the USA, but they examine the impact of EPU not only on housing prices but also housing investment. The results show that higher EPU will raise housing investment growth but reduce housing prices inflation in 48 US states.

Strobel et al. (2020) select a different uncertainty index to study how economic uncertainty affects regional housing markets in the USA. They apply the JLN macroeconomic uncertainty index, an unobservable measure of economic uncertainty, which is calculated based on the volatility of the unforecastable component of a large group of important economic indicators and can capture the overall macroeconomic uncertainty. Their empirical findings provide the evidences of macroeconomic uncertainty causing significant effects on regional housing markets in the USA.

This paper also set up a housing prices model covering economic uncertainty variables, same as Choudhry (2020), but we apply two JLN economic uncertainty indices, not EPU, to examine the effect of economic uncertainty on regional housing markets. Furthermore, to investigate how lower and higher degrees of macroeconomic and financial uncertainty have different effects on regional housing prices, this paper will employ the panel threshold regression method of Hansen (1999) to estimate the nonlinear impacts.

3 Housing model and methodology

3.1 The theoretical model of housing prices equilibrium

This paper establishes a housing model with economic uncertainty to explore the effect of the latter on housing prices. We first apply the equilibrium model of Di Pasquale and Wheaton (1994) and Adams and Füss (2010) as the main theoretical framework. The housing demand function is described in Eq. (1):

$$D_t = \alpha_0 - \alpha_1 \mathrm{HSp_t} + \alpha_2 \mathrm{ECa}_t - \alpha_3 \mathrm{Lr}_t + \widetilde{\varepsilon}_t \tag{1}$$

In Eq. (1), rising housing prices (HSpt) and interest rates (Lr_t) lead to the reductions in housing demand. In contrast, greater economic activity (ECa_t) increases housing demand.

The housing supply is determined as in Eq. (2):

$$S_t = \psi_0 + \psi_1 \mathrm{HSp}_t - \psi_2 \mathrm{CONc}_t + \widetilde{u}_t \tag{2}$$

In Eq. (2), higher housing prices induce increases in housing supply, but higher construction costs (CONc_t) will reduce housing supply and housing prices.

As housing demand equals housing supply ($D_t = S_t$), a housing price equilibrium can be described as in Eq. (3):

$$\mathrm{HSp}_t = b_1 + b_2 \mathrm{ECa}_t - b_3 \mathrm{Lr}_t + b_4 \mathrm{CONc}_t + \varepsilon_t \tag{3}$$

In Eq. (3), greater economic activity (ECa_t) increases housing demand. Interest rates (Lr_t) reduce housing demand. Many studies confirmed economic activity positively impacts housing prices (Bardhan, et al., 2007; Grum & Govekar, 2016), but the variable of economic activity has been measured via different indicators, such as GDP, industrial production, monetary supply, consumption, and employment. Adam and Füss (2010) created an index of economic activity, consisting of five macroeconomic variables, including real money supply, real consumption, real industrial production, real GDP and employment, by applying the first principal component of the matrix. Similarly to Adam and Füss (2010), this paper calculates economic activity using the principal components of real money supply, real consumption, real industrial production, real GDP, and employment.

Interest rate (Lr_t) is expected to reduce housing demand. Both Levin and Pryce (2009) and Harris (1989) argued greater housing demand and rising housing prices are caused by falling real interest costs. As regards the effect of construction costs (CONc_t) on housing prices, Gyourko and Saiz (2006) identified a positive and significant impact of real construction costs on real housing prices due to the manner in which construction costs affect the housing supply.

Recently, it has also been found economic uncertainty can influence housing markets. The standard housing model does not consider the effect of economic uncertainty. In reality, economic uncertainty can impact the housing market in different ways. First, greater uncertainty will cause real estate developers to postpone new construction, which further reduces housing supply. Next, households may consume less durable goods when they face higher uncertainty, which will then reduce housing demand. On the other hand, housing is an important component of investment portfolios, and so greater uncertainty could also increase housing demand and housing prices if the demand for other assets is more sensitive to uncertainty (El-Montasser et al., 2016). Hence, the effect of economic uncertainty on housing prices is ambiguous. However, considering the significant effect of economic uncertainty on housing prices, some recent studies established a housing model incorporating economic policy uncertainty.

Following the example of Choudhry (2020), this paper also establishes a housing price model incorporating economic uncertainty, but we focus on the effects of two JLN macroeconomic and financial uncertainty indices, not EPU, on housing markets. Equation (4) can be revised as follows:

$$\mathrm{HSp}_t = b_1 + b_2\mathrm{ECa}_t + b_3\mathrm{Lr}_t + b_4\mathrm{CONc}_t + b_5\mathrm{MU}_t + b_6\mathrm{FU}_t + \varepsilon_t \tag{4}$$

In Eq. (4), the two JLN indices of macroeconomic uncertainty (MU_t) and financial uncertainty (FU_t) are included. The JLN macroeconomic and financial uncertainty indices offer a summary of the unforeseeable components of macroeconomic and financial variables, and thus can provide a good estimation of unanticipated changes in the underlying drivers of housing prices. Jurado et al. (2015) defined macroeconomic and financial uncertainty as the volatility of the unforeseeable component of a data-rich set including vital economic indicators. According to the framework of Jurado et al. (2015), the uncertainty index should be as independent as possible from theoretical models, and it not just depend on a single observable economic indicator. They calculated MU and FU via a data set addressing the individual uncertainties of 132 macroeconomic series and 147 financial series, respectively. Based on these macroeconomic or financial series' variables, they employed the methodology of principal components to catch latent factors and applied the VAR to obtain each variable's forecast error variance, and then constructed MU and FU comprising an average across the conditional stochastic volatilities of the estimated forecasting error.

Previous studies derived inconsistent results regarding the effect of economic uncertainty on housing prices. Han (2008) emphasized how economic uncertainty can positively affect housing prices—if investors buy houses at low prices expecting a future rapid recovery, they will increase housing demand to hedge their future price. On the other hand, economic uncertainty could also negatively affect housing prices. Christou et al. (2019) discovered uncertainty shocks reduce housing variables. If there is greater uncertainty in the housing market, investors and house buyers could delay investing or buying until the market becomes more stable, resulting in reduced housing prices and sales. Moreover, greater economic uncertainty can reduce housing supply because real estate developers often postpone construction when facing greater uncertainty. In other words, greater economic uncertainty can reduce both housing demand and supply, with ambiguous effects on housing prices.

3.2 Panel threshold regression

The panel threshold regression model was proposed by Hansen (1999). The single threshold regression model is as follows:

$$y_{it} = \theta_1 x_{it} + e_{it} \quad \text{for } q_{it} \leq \gamma \tag{5}$$

$$y_{it} = \theta_1 x_{it} + e_{it} \quad \text{for } q_{it} \leq \gamma \tag{6}$$

where i and t represent the metropolitan area and the year, respectively; y and x are the dependent and independent variables, respectively; q is the threshold variable, while γ represents the threshold quantity, and e represents the residual term. The combination of Eqs. (5) and (6) can be rewritten as follows:

$$y_{it} = \theta_1 x_{it} I\left(q_{it} \leq \gamma\right) + \theta_2 x_{it} I\left(q_{it} > \gamma\right) + \mu_i + e_{it} \tag{7}$$

$I(\cdot)$ is the indicative function, with the value of the condition in parentheses being either 1 or 0.

We assume that $\theta' = (\theta_1, \theta_2)$; as a result, Eq. (7) can be rewritten as Eq. (8).

$$y_{it} = \theta' x_{it}(\gamma) + \mu_i + e_{it} \tag{8}$$

Hansen (1999) suggested estimating γ by using LS to minimize the concentrated SSE, which is denoted as S_1. Hence, the estimator of γ is:

$$\widehat{\gamma} = \operatorname{argmin} S_1(\gamma)$$

After the individual fixed effect has been removed from the model by removing the individual mean, the average of Eq. (8) can be obtained:

$$Y^* = \theta X^*(\gamma) + e^* \tag{9}$$

The coefficient can be calculated as $\widehat{\theta}(\gamma) = (X^*(\gamma)' X^*(\gamma))^{-1} X^*(\gamma)' Y^*$, and the residual value is $\widehat{e}^*(\gamma) = Y^* - X^*(\gamma)\widehat{\theta}(\gamma)$. The sum of squared (SSE) is shown in Eq. (10):

$$S_1(\gamma) = \hat{e}^*(\gamma)'\hat{e}^*(\gamma) = Y^{*\prime}\left(I - X^*(\gamma)'(X^*(\gamma)\right)'X^*(\gamma)^{-1}X^*(\gamma)'Y^* \tag{10}$$

After $\widehat{\theta} = \widehat{\theta}(\widehat{\gamma})$ and $\hat{e}^* = \hat{e}^*(\hat{\gamma})$ are calculated, the estimator of residual variance, $\hat{\sigma}^*$, in Eq. (9) can be obtained via Eq. (11).

$$\hat{\sigma}^2 = \frac{1}{n(T-1)} \hat{e} *, \ \hat{e} *= \frac{1}{n(T-1)} S_1(\hat{\gamma}) \tag{11}$$

The confidence interval and critical value are determined via Eqs. (12) and (13), respectively:

$$\mathrm{LR}_0(\gamma) = (S_1(\gamma) - \mathrm{S}_1(\hat{\gamma}))/\hat{\sigma}^2. \tag{12}$$

$$c(\alpha) = -2 \log\left(1 - \sqrt{1-\alpha}\right) \tag{13}$$

If $\mathrm{LR}_0(\gamma)$ exceeds $c(\alpha)$ and the threshold value of $\hat{\gamma}$ is within the confidence interval, the null hypothesis of no threshold effect should be rejected. However, there may be multiple thresholds in the regression. To examine the nonlinear effect of economic uncertainty on housing prices, we establish a model with a maximum of three thresholds, as follows:

$$y_{it} = \theta_1 x_{it} I(q_{it} \le \gamma_1) + \theta_1 x_{it} I(\gamma_1 \le q_{it} \le \gamma_2) + \theta_1 x_{it} I(\gamma_2 \le q_{it} \le \gamma_3) + \theta_1 x_{it} I(\gamma_3 \le q_{it}) + \mu_i + e_{it} \tag{14}$$

The order of the thresholds is $\gamma_1 < \gamma_2 < \gamma_3$, and this will be applied to construct the confidence intervals for the threshold parameters.

4 Data and empirical results

4.1 Data

We employ quarterly dataset ranges from 1991Q1 to 2019Q4. Data regarding the economic activity variable and the long-term interest rate are taken from the IMF database. We calculate economic activity using the principal components of real money supply, real consumption, real industrial production, real GDP, and employment. The construction cost is taken from the survey of construction (SOC) performed by the US Census Bureau. To assess the effect of uncertainty on housing prices, we use two JLN indices, macroeconomic uncertainty (MU) and financial uncertainty (FU), for the measurement of economic uncertainty in the USA. The data for US regional housing prices have been published by the US Federal Housing Finance Agency. The 50 metropolitan housing price values we employ are divided into four regions: Midwest, Northeast, South, and West. Table 1 presents each variable's code, definition, and data source.

Table 2 presents the members in each region and their housing price statistics. The Midwest metropolitan area consists of 11 cities, while there are 9, 14, and 16 cities in the Northeast, West, and South regions, respectively. Table 2 shows that many cities' housing prices in the West are higher—5 of the 10 metropolitan areas with the highest housing prices are in the West region, including Portland–Vancouver–Hillsboro (246.64), Denver–Aurora–Lakewood (233.01), Seattle–Bellevue–Kent (200.70), San Francisco–San Mateo–Redwood City (197.47), and San Jose–Sunnyvale–Santa Clara (192.11). The standard deviations of housing prices in these five metropolitan areas are also the highest, and there are generally higher standard deviations in the metropolitan areas in the West region. The lowest housing prices can be found in the Midwest area, including values of 131.90 for Detroit–Dearborn–Livonia and 132.67 for Cleveland–Elyria. Moreover, in the Midwest, except for Minneapolis–St. Paul–Bloomington, all the standard deviations are around 20 to 40, implying more stable housing prices. The Northeast and South regions have average housing prices between 140 and 213.

The trends for each variable are presented in Figs. 1, 2, 3, 4, 5 and 6. As shown in Fig. 1, housing prices presented a rising trend that grew until the end of 2006, while the 2008–2009 global financial crisis caused a huge drop in housing prices until 2012Q1, after which they began to rise again for the rest of the period. Economic activity (Fig. 2) was highest in 2019Q3 and lowest in 1992Q1. Furthermore, economic activity in the USA showed a positive trend, rising almost 65% from the beginning of the period. Similar to the economic activity trend, construction cost, as shown in Fig. 3, was highest in 2019Q3 and lowest in 1992Q1, and it continued growth after 2009Q1. Figure 4 shows that the interest rate decreased over the sample period. The trends in MU and FU are shown in Figs. 5 and 6, respectively; both reached their highest level during the

Table 1 Data and sources

Code	Variable	Data resources
ECa	Economic activity	The variable is a combined variable of five macroeconomic factors, including real money supply, real consumption, real industrial production, real GDP, and employment. These four real variables are calculated to apply nominal variables being deflated by consumer price index. The data of four nominal variables and CPI are taken from IMF
CONc	Construction cost	The data is from the survey of construction (SOC) from The U.S. Census Bureau
Lr	Long term interest rate	10 years government Bond, and the data is from IMF
MU	Macroeconomic uncertainty	The two indices are measured by Jurado, et al. (2015), and data is from www.sydneyludvigson.com/data-and-appendixes
FU	Financial uncertainty	
HSp	Housing prices changes	US metropolitan area housing prices index taken from the US Federal Housing Finance Agency Housing prices changes measured by the first difference of housing prices

Table 2 Descriptive statistics of each metropolitan area's housing prices

No	Metropolitan city	Housing prices statistics		
		Mean	Median	SD
Midwest region				
1	Cincinnati	143.33	145.15	22.94
2	Cleveland–Elyria	132.67	130.05	20.61
3	Columbus	146.77	147.92	27.06
4	Kansas City	163.61	175.63	41.22
5	St. Louis	148.63	155.06	30.43
6	Milwaukee–Waukesha	172.48	183.64	41.56
7	Minneapolis–St. Paul–Bloomington	186.23	196.58	61.51
8	Chicago–Naperville–Evanston	153.52	153.20	37.57
9	Indianapolis–Carmel–Anderson	139.54	141.14	22.96
10	Detroit–Dearborn–Livonia	131.90	131.75	43.04
11	Warren–Troy–Farmington Hills	148.34	154.03	39.02
Northeast region				
1	Boston	190.29	225.03	77.15
2	Cambridge–Newton–Framingham	188.89	221.52	73.56
3	Nassau County–Suffolk County	180.61	216.39	70.56
4	New York–Jersey City–White Plains	170.85	201.72	62.66
5	Montgomery–Bucks–Chester County	148.38	172.20	42.22
6	Newark	165.07	184.46	53.75
7	Philadelphia	156.64	187.06	55.94
8	Pittsburgh	149.24	158.57	32.51
9	Providence–Warwick	160.07	180.35	58.04
West region				
1	Anaheim–Santa Ana–Irvine	171.27	196.16	80.93
2	Los Angeles–Long Beach–Glendale	149.34	156.98	72.95
3	Oakland–Berkeley–Livermore	175.77	173.18	81.87
4	Riverside–San Bernardino–Ontario	135.38	123.73	59.60
5	Sacramento–Roseville–Folsom	144.01	138.44	59.57
6	San Diego–Chula Vista–Carlsbad	170.40	183.91	77.20
7	San Francisco–San Mateo–Redwood City	197.47	213.98	102.24
8	San Jose–Sunnyvale–Santa Clara	192.11	202.36	89.62
9	Portland–Vancouver–Hillsboro	246.64	263.82	105.75
10	Las Vegas–Henderson–Paradise	151.18	138.31	54.94
11	Seattle–Bellevue–Kent	200.70	209.51	89.60
12	Washington–Arlington–Alexandria	161.83	180.89	60.43
13	Denver–Aurora–Lakewood	233.01	247.72	98.25
14	Phoenix–Mesa–Chandler	178.72	171.85	68.26
South region				
1	Fort Lauderdale–Pompano Beach–Sunrise	171.27	164.45	72.53
2	Jacksonville	160.64	163.30	48.74
3	Miami–Miami Beach–Kendall	192.49	186.85	89.28
4	Orlando–Kissimmee–Sanford	150.12	140.89	52.94
5	Tampa–St. Petersburg–Clearwater	157.98	154.81	55.74

Table 2 (continued)

No	Metropolitan city	Housing prices statistics		
		Mean	Median	SD
6	West Palm Beach–Boca Raton–Boynton Beach	158.88	156.60	63.46
7	Atlanta–Sandy Springs–Alpharetta	143.59	144.78	32.25
8	Nashville–Davidson–Murfreesboro–Franklin	174.13	182.67	57.86
9	Baltimore–Columbia–Towson	155.57	182.08	48.58
10	Virginia Beach–Norfolk–Newport News	172.44	206.87	62.00
11	Charlotte–Concord–Gastonia	153.02	155.21	35.12
12	Austin–Round Rock–Georgetown	213.56	211.80	88.34
13	Dallas–Plano–Irving	153.93	156.86	49.91
14	Fort Worth–Arlington–Grapevine	151.41	155.33	45.58
15	Houston–The Woodlands–Sugar Land	157.68	166.46	47.97
16	San Antonio–New Braunfels	169.71	176.81	52.38

Fig. 1 Housing prices

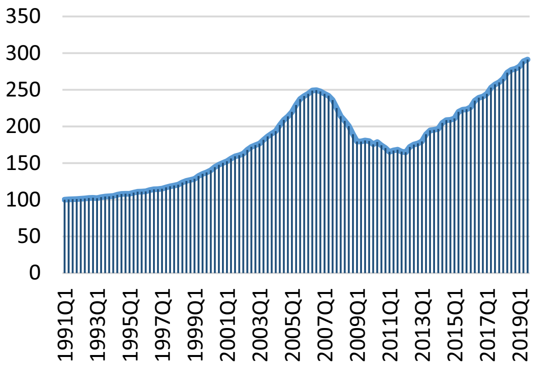
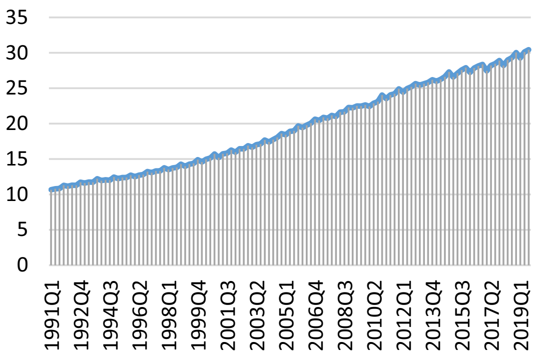


Fig. 2 Economic activity



crisis of 2008. Excluding the 2008–2009 financial crisis, MU was also highest around 2000 ~ 2001 and 2015, displaying lower levels in other periods. Compared with MU, FU showed the greatest fluctuations over the sample period. Excluding the 2008–2009

Fig. 3 Construction cost

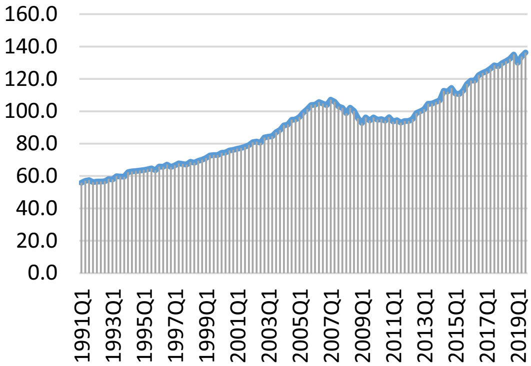


Fig. 4 Interest rate

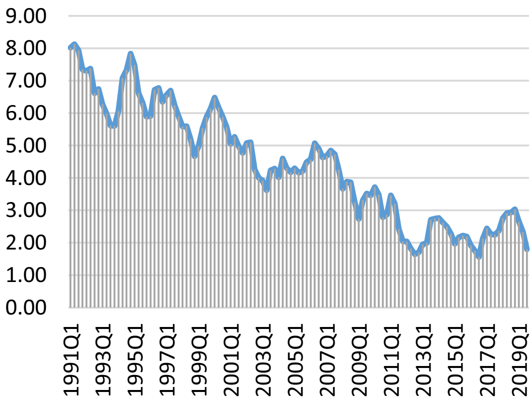
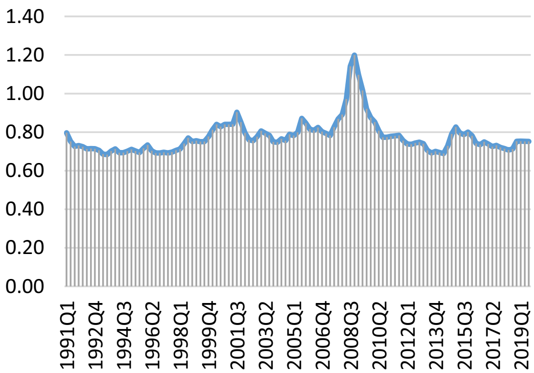


Fig. 5 Macroeconomic uncertainty



financial crisis, FU reached its level in 1999–2003, 2011, and after 2018, implying financial variables are more unstable in the USA.

Fig. 6 Financial uncertainty

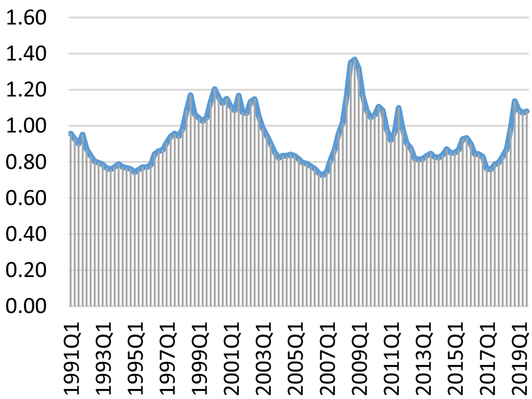


Table 3 Results of panel regression

	Full sample	Midwest region	Northeast region	West region	South Region
dLr	−0.02***	−0.14***	−0.03***	−0.02***	−0.04***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
dCONc	0.57***	0.47***	0.51***	0.7***	0.54***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
dECa	0.30***	0.30***	0.36***	0.28***	0.28***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
MU	−0.09***	−0.12***	−0.06***	−0.12***	−0.06***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
FU	0.01***	0.02***	0.03***	0.02***	−0.02***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Notes: *** and ** indicate statistical significance at the 1, 5, and 10% levels, respectively, and *t*-value is in brackets

4.2 Basic panel regression

Prior to panel threshold regression, we perform the basic panel regression with fixed effects to estimate Eq. (4),[3] and Table 3 presents the results. Table 3 shows all variables can significantly affect housing prices; the key results are as follows:

First, interest rates can negatively affect housing prices, implying a higher interest rate will reduce housing prices. Conversely, economic activity and construction costs will positively impact housing prices. These results conform to the hypotheses. Further, comparing the absolute values of three macroeconomic variables' coefficients, interest rate (dLr) has the greatest effect on housing prices in the Midwest region. The greatest impact of

[3] To avoid the spurious regression, all variables in Eq. (4) must be stationary. In Eq. (4), the dependent variable and three independent macroeconomic variables are stationary because they are first differences. Based on the ADF test of the model with trend, the ADF statistics are − 3.50 for MU and − 2.95 for FU, confirming MU and FU are also stationary.

Table 4 Tests for the number of MU threshold effects

	Full sample	Midwest region	Northeast region	West region	South region
Single threshold					
$F1$	162.53***	73.46***	38.95***	81.52***	73.26***
P-Value	0.00	0.00	0.00	0.00	0.00
Double threshold					
$F1$	99.55	34.95	23.97	45.11	30.27
P-Value	0.32	0.70	0.16	0.97	0.21
Triple threshold					
$F1$	93.43	35.03	26.32	28.37	46.10
P-Value	0.31	0.72	0.40	0.21	0.32

Notes: *** and ** indicate statistical significance at the 1, 5, and 10% levels, respectively

construction cost (dCONc) on housing prices is found in the West, while the effects of economic activity (dECa) in the Northeast are higher than in the other three regions.

Second, the effect of MU on each region's housing prices is negative, and the effect is higher in the Midwest and West. The negative effect of MU shows greater macroeconomic risk will reduce housing demand and further lower housing prices. This result is similar to that of Christou et al. (2019), who investigated the impact of macroeconomic uncertainty on US housing variables, finding uncertainty can negatively affect housing variables. Housing demand is lowered by households' reduced consumption of durable goods when facing greater uncertainty about future employment, income and wealth. Further, Bernanke (1983) explained the negative effect of uncertainty on housing prices via the fact housing is an irreversible form of investment, and investors will delay decisions under conditions of high uncertainty. Craine (1989) also stated incomplete markets and risk-aversion will negatively affect housing investment.

Except for in the South, FU's effect is positive in the regions, and the largest effect of FU was found in the Northeast, meaning greater financial uncertainty will increase housing prices in most regions. El-Montasser et al. (2016) argued uncertainty could positively affect housing demand and prices when the demand for other assets is more sensitive to uncertainty. Moreover, greater financial uncertainty could reduce housing supply and demand simultaneously, and financial uncertainty positively affects housing prices if the reduction in housing supply is great. As regards the South, both higher economic uncertainty and higher financial uncertainty will have adverse effects on housing prices.

4.3 Panel threshold regression using MU as the threshold variable

The responses of house prices to fundamental changes will differ when gauged at different levels of economic uncertainty. Hence, this section further tests the varying effects of economic variables on housing prices under different levels of MU by applying panel threshold regression. As demonstrated by Hansen (1999), if a threshold effect is present, then the existing number of threshold effects, whether triple-, double-, or single-threshold, must be examined. The bootstrap method is applied to approximate the F statistics and then calculate the p-values. Based on 300 bootstrap procedures for each threshold test, Table 4 provides the statistics for $F1$, $F2$, and $F3$ and their bootstrap p-values, using MU as the threshold variable. Table 4, addressing the full sample, shows

Table 5 The threshold value of MU

Region	Estimate of threshold value	95% confidence interval	
		Lower	Upper
Full sample	$r1 = 0.9207$	0.9032	0.9714
Midwest region	$r1 = 0.8771$	0.8707	0.9014
Northeast region	$r1 = 0.9207$	0.7932	0.9714
West region	$r1 = 0.9207$	0.9032	0.9714
South region	$r1 = 0.9207$	0.9032	0.9714

Notes: the threshold estimate is the point where the likelihood ratio equals zero

Table 6 Results of threshold regression with MU threshold variable

Variable	Full sample MU ≤ 0.9207	Midwest region MU ≤ 0.8771	Northeast region MU ≤ 0.9207	West region MU ≤ 0.9207	South region MU ≤ 0.9207
First regime (Low level)					
dLr	−0.03***	−0.02***	−0.02***	−0.01	−0.03***
	(0.00)	(0.00)	(0.00)	(0.19)	(0.00)
dCONc	0.002***	0.42***	0.54***	0.78***	0.56***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
dECa	0.02***	0.29***	0.37***	0.29***	0.29***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
MU	−0.36***	−0.14***	−0.12	−0.05***	−0.01***
	(0.00)	(0.00)	(0.37)	(0.00)	(0.20)
FU	0.06***	0.02***	0.03***	0.02**	0.01***
	(0.00)	(0.00)	(0.00)	(0.02)	(0.00)
Second regime (High level)					
dLr	0.20***	0.30***	0.11**	0.15**	0.25***
	(0.00)	(0.00)	(0.02)	(0.02)	(0.00)
dCONc	−0.43***	−0.53	−0.25	−0.47**	−0.69***
	(0.00)	(0.14)	(0.14)	(0.05)	(0.00)
dECa	0.16***	0.08	0.05	−0.49	0.28
	(0.00)	(0.85)	(0.82)	(0.08)	(0.28)
MU	−1.15***	−0.55***	0.003	0.29	−0.27
	(0.00)	(0.01)	(0.97)	(0.07)	(0.07)
FU	1.15***	0.40**	−0.06	−0.47***	0.18
	(0.00)	(0.05)	(0.57)	(0.00)	(0.20)

Notes: *** and ** indicate statistical significance at the 1, 5, and 10% levels, respectively, and t-value is in brackets

the test for a single threshold ($F1$) gave significant results, with a bootstrap p-value of 0.00, while the double threshold ($F2$) gave a p-value of 0.32 and the triple threshold ($F3$) gave a p-value of 0.31, confirming MU has a single threshold effect on housing prices for the full sample. Similarly, in all four regions, the test for a single threshold ($F1$) gave significant results, but the results for a double threshold ($F2$) and a triple threshold ($F3$) were insignificant, showing MU has a single-threshold effect on housing prices for all regions.

Table 5 reports the unrefined first-step likelihood ratio function LR(γ), which is computed when establishing a single threshold model. We found at the 0.9207 point, the likelihood ratio hits the zero axis and divides the MU variable into two regimes for four cases—the full sample, as well as the Northeast, West and South regions. The Midwest region hits the zero axis at 0.8771 and splits into two regimes at MU $\leq$ 0.8771.

Based on a single threshold effect, the threshold regression estimates of Eqs. (2–4), using MU as the threshold variable, are displayed in Table 6.

The following can be derived from Table 6:

First, as regards the three economic variables, in the first regime (the low regime) for all regional samples, the coefficient of the interest rate (dLr) is negative, and the coefficients of the construction cost (dCONc) and economic activity (dECa) are positive; further, most are significant, which conforms to the results of basic panel regression in Table 3. The coefficients of the three variables differ in the second regime (the high regime). In the second regime for most of the regions, the coefficient of interest rate (dLr) becomes positive and that of construction cost (dCONc) becomes negative, while the coefficient of economic activity (dECa) stays positive but becomes insignificant. Hence, as MU moves from low to high, the effect directions of interest rate and construction cost on housing prices will change, and the effect of economic activity becomes insignificant. This implies if macroeconomic uncertainty is low, the effects of all three variables will be as predicted. However, when macroeconomic uncertainty is high, high economic risk will suppress normal housing demand and investment, causing a decline in housing prices; even when interest rates drop. Similarly, a high level of macroeconomic uncertainty will also cause construction costs and economic activity to have abnormal or invalid effects on housing prices, while rising construction costs and economic activity could reduce housing prices, if they have any effect at all, because high economic risk suppresses normal housing demand and investment.

Second, the coefficient of macroeconomic uncertainty (MU) is negative in both regimes for all cases, except for the second regime of the Northeast and West regions. In the second regime, the coefficient remains significant for the Midwest, but becomes insignificant for the other three regions. Hence, if the macroeconomic risk is low, increasing macroeconomic uncertainty can significantly reduce housing prices in most regions, which agrees with the results for basic panel regression in Table 3. Inversely, if the macroeconomic risk is high, this will have an insignificant effect on the macroeconomic uncertainty in housing prices. Why is the effect of MU insignificant in the high regime of MU in most regions? Greater economic uncertainty can reduce both housing supply and demand. In the low regime of macroeconomic risk, rising MU usually causes a larger reduction in housing demand than housing supply, because real estate developers will treat this risk as a normal risk and will not substantially change the original development plan. Differently, if the macroeconomic risk is in the high regime, rising economic uncertainty could become an immense risk and exceed the risk level of the real estate developers' tolerance, causing many real estate developments to stop or be postponed and further lead to a larger reduction in housing supply. Hence, in the high regime of MU, rising economic uncertainty could also cause a larger reduction in housing supply and demand simultaneously, and the decreases in housing prices become insignificant due to the similar reduction in the size of housing supply and demand.

Third, the coefficient of financial uncertainty (FU) is positive in both regimes for most of the cases, except for the second regime of the Northeast and West regions. In the

Table 7 Tests for the number of FU threshold effects

	Full sample	Midwest region	Northeast region	West region	South region
Single threshold					
*F*1	236.63***	72.63***	46.81**	46.81***	75.01***
P-Value	0.00	0.00	0.02	0.01	0.01
Double threshold					
*F*1	159.34***	32.12	34.27***	34.27***	47.15***
P-Value	0.00	0.84	0.01	0.00	0.00
Triple threshold					
*F*1	99.30	32.71	20.35	20.35	60.54
P-Value	0.87	0.94	0.55	0.60	0.79

Notes: *** and ** indicate statistical significance at the 1, 5, and 10% levels, respectively

Table 8 Threshold value of FU

Region	Estimate of threshold value	95% confidence interval	
		Lower	Upper
50 Metropolitan areas	$r1 = 0.8771$	0.8707	0.9019
	$r2 = 1.1684$	1.1668	1.1685
Midwest region	$r1 = 0.8771$	0.8707	0.9014
Northeast region	$r1 = 0.9023$	0.8771	0.9067
	$r2 = 1.1684$	0.9824	1.1685
West region	$r1 = 0.9023$	0.8771	0.9067
	$r2 = 1.1684$	0.9824	1.1685
South region	$r1 = 0.9023$	0.9023	0.9067
	$r2 = 1.1684$	1.1668	1.1860

Notes: the threshold estimate is the point where the likelihood ratio equals zero

second regime, the coefficient remains significant and increases for the Midwest region, while it becomes insignificant for the Northeast and South regions, and becomes significantly negative for the West. Therefore, if the macroeconomic risk is low, increases in financial uncertainty can increase housing prices in all regions, agreeing with the results of basic panel regression; however, the effect of financial uncertainty on housing prices will be ambiguous and differentiated in various regions if the macroeconomic risk becomes high.

When comparing the effects of the two kinds of uncertainty on housing prices in the four regions (Table 6), we see the negative impact of macroeconomic uncertainty is significant, and is the highest in the Midwest region in both regimes, implying macroeconomic uncertainty will have the highest negative impact on housing prices in this region. In the Midwest and West regions, financial uncertainty will have a greater negative impact on housing prices when the MU is high. Housing investors should be cautious as to the effects of economic risk in these two regions.

Table 9 Results of threshold regression with FU threshold variable

Variable	Full sample	Midwest region	Northeast region	West region	South region
	FU ≤ 0.8771	FU ≤ 0.8771	FU ≤ 0.9023	FU ≤ 0.9023	FU ≤ 0.9023
First regime (Low regime)					
dLr	0.02***	−0.01	0.01**	0.01**	0.01**
	(0.00)	(0.85)	(0.04)	(0.04)	(0.05)
dCONc	0.36***	0.26***	0.36***	0.36***	0.31***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
dECa	0.17***	0.22***	0.32***	0.32***	0.17***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
MU	0.02**	−0.12***	0.04**	0.04***	0.06***
	(0.03)	(0.00)	(0.02)	(0.00)	(0.00)
FU	0.12***	0.10***	0.10***	0.10**	0.05***
	(0.00)	(0.00)	(0.00)	(0.02)	(0.00)
	0.8771 < FU ≤ 1.1684	0.8771 < FU	0.9023 < FU ≤ 1.1684	0.9023 < FU ≤ 1.1684	0.9023 < FU ≤ 1.1684
Second regime (Middle regime)					
dLr	−0.04***	−0.02**	−0.04**	−0.03***	−0.05***
	(0.00)	(0.03)	(0.02)	(0.00)	(0.00)
dCONc	0.62***	0.57***	0.51***	0.76***	0.51***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
dECa	0.20	0.20***	0.25***	0.20	0.22***
	(0.75)	(0.00)	(0.00)	(0.99)	(0.00)
MU	−0.11**	−0.15***	−0.13***	−0.17***	−0.10***
	(0.03)	(0.00)	(0.00)	(0.00)	(0.00)
FU	0.08***	0.07***	0.12***	0.15***	0.08***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Table 9 (continued)

	FU > 1.1684	FU > 1.1684	FU > 1.1684	FU > 1.1684
Third regime (High regime)				
dLr	0.46***	0.46***	0.65***	0.47***
	(0.00)	(0.00)	(0.00)	(0.00)
dCONc	−3.24***	−3.67***	−4.82***	−3.21***
	(0.00)	(0.00)	(0.00)	(0.00)
dECa	0.22	0.28	0.44***	0.29
	(0.11)	(0.23)	(0.00)	(0.26)
MU	−0.23***	−0.15***	−0.38***	−0.23***
	(0.00)	(0.00)	(0.00)	(0.00)
FU	−0.67***	−0.87***	−0.87***	−0.63***
	(0.00)	(0.00)	(0.00)	(0.00)

Notes: *** and ** indicate statistical significance at the 1, 5, and 10% levels, respectively, and *t*-value is in brackets

4.4 Panel threshold regression using FU as threshold variable

This section assesses the effects of using FU as the threshold variable in the model. Table 7 provides the statistics for $F1$, $F2$, and $F3$ and their bootstrap p-values. Table 7 shows, excluding the Midwest region, FU has a double-threshold effect on housing prices for the full sample and the other three regions. On the other hand, a single threshold effect can be seen in the Midwest region.

Table 8 provides the optimum likelihood ratio for each threshold model and their asymptotic 95% confidence intervals. The FU for the Midwest will be divided into two regimes, and that for the full sample and other three regions will be divided into three.

The threshold regression estimates of Eq. (4), using FU as the threshold variable, are displayed in Table 9, which presents the following findings.

First, in the first regime (low level), the coefficients of all variables are positive, and all are significant except for interest rate, implying if financial risk is low, besides the positive impacts of construction cost and economic activity, the interest rate and both kinds of uncertainty will also positively affect housing prices, because increasing interest rates and both kinds of uncertainty could be caused by expanded business cycles.

Next, in the second regime (the middle regime), the coefficients of all variables are the same sign as in the basic panel regression, as shown in Table 3, and they are significant for all regions, except for that of economic activity in the full sample. In other words, if financial uncertainty is in the middle regime, the effects of all variables on housing prices will be as theoretically expected, and will conform to the results of basic panel regression.

Further, in the third regime (the high regime), the coefficient of macroeconomic uncertainty is significantly negative for all regions (the same as the result in the second regime), but the coefficients of the other four variables here differ from those in the second regime. The coefficient of interest rate (dLr) becomes positive, while the coefficients of construction cost (dCONc) and financial uncertainty (FU) become negative. The coefficient of economic activity (dECa) remains positive but becomes insignificant. As such, when FU becomes high, the effect directions of interest rate and construction cost on housing prices will change, and the effect of economic activity will become insignificant in most regions. As to the effects of the two uncertainty variables when FU is in the third regime, compared with their effects in the second regime, the negative effect of macroeconomic uncertainty (MU) is amplified, and the effect of financial uncertainty (FU) becomes negative. This shows regardless of whether macroeconomic risk or financial risk is increased, if either becomes high, housing demand and investment will drop, and housing prices will decrease.

Finally, the coefficients of financial uncertainty (FU) are significantly positive in the first and second regimes (the low and middle regimes) for all cases, but become significantly negative in the third regime (the high regime), showing increasing financial uncertainty significantly increases housing prices in all US regions that are in the low and middle regimes of financial risk, while having a negative effect on those under high financial risk. In other words, if financial risk is low, investors will be willing to take on higher risks, which causes housing prices to increase. The best explanation for this is Minsky's (1980) instability hypothesis, which explains economic agents will increase their risk-taking when exposed to low financial risk. Bhattacharya et al. (2015) also offered similar arguments. Conversely, if financial uncertainty is high, rising financial risk will decrease housing prices. Bansal and Yaron (2004) indicated people will increase their precautionary saving behaviors and reduce their consumption when under highly uncertain conditions, which will reduce housing demand and further lead to lower housing prices. Acharya and Pedersen (2005) proved increases in financial uncertainty encourage investors to withdraw their housing investment, resulting in reductions in housing prices. However, if financial uncertainty is too high, such as under the third regime of financial uncertainty, investors will reduce their housing investment so as to avoid taking too high an investment risk, which will cause housing prices to fall.

Note, comparing the effects of the two kinds of uncertainty in the four regions (Table 9), their negative impacts are both significant and higher in the West when under the high regime, implying these two kinds of economic uncertainty can cause drastic changes in housing prices in this region. As such, regardless of whether macroeconomic or financial uncertainty are increasing, housing investors in the West should adopt more conservative investment and hedging strategies when financial risk is high. In the Northeast region, financial uncertainty has a similar effect on housing prices when undergoing high financial risk.

Except for using MU and FU as the variable of economic uncertainty, we also examine the effect of EPU on regional housing prices, and Appendix 1 presents the results of panel threshold regression using EPU as the index of economic uncertainty. Further, we employ threshold regression examining the effect of MU and FU using the data of 12 individual city's housing prices, and the results are shown as Appendix 2.

4.5 Discussion of the effect of uncertainty

Reviewing the empirical results of the effect of economic uncertainty on regional housing prices in literature, most of these studies used EPU as economic uncertainty and found the effect of EPU on housing prices is negative. Employing the state data in the USA, Christidou and Fountas (2017) showed higher EPU will reduce housing price inflation. Bahmani-Oskooee and Ghodsi (2017) also used the data of 50 US states, and they found the long-run effect of EPU on regional housing prices is significantly negative in 16 states. Applying 10 regional house prices of England and Wales, Choudhry (2020) also supported the negative effect from EPU on regional housing prices. Strobel et al. (2020) employed MU index of Jurado et al. (2015), not EPU, to study this effect. They found MU shocks decrease housing prices and the effects are larger in the states with higher housing price volatility.

In light of the empirical results in this study, the effect of MU is negative for all cases of linear regression and most cases of threshold regression, as with the results of the above literature. However, there are some exceptional cases, such as the effect of MU is positive under the low regime of FU for most regions, the reason is investors will be willing to take on higher-risk housing investments if financial risk is low, leading to increased housing prices as MU rises. As to the effect of FU, it is positive for all cases of linear regression and most cases of threshold regression, but the effect of FU is negative under the high regime of FU for most of the regions, because increasing FU will reduce housing demand and investments if financial risk is too high for housing buyers, causing decreases in housing prices. Nevertheless, the above relevant literature did not explore the effect of FU.

5 Conclusion

This study employs panel threshold regression to estimate the nonlinear effect of macroeconomic and financial uncertainty on regional housing prices in the USA. The empirical model is based on that of Adams and Füss (2010), covering the two economic uncertainty indices of Jurado et al. (2015). The samples covers the 50 largest metropolitan areas in the US from 1991Q1 to 2019Q4, and these areas are divided into four panels: Midwest, Northeast, South, and West. The empirical results are summarized as follows:

First, regardless of whether one is using macroeconomic uncertainty (MU) or financial uncertainty (FU) as the threshold variable, the results of panel threshold regression confirm the nonlinear effect. A single threshold effect can be detected when using MU as the threshold variable for all regions, while a single threshold effect in the Midwest region and a double threshold effect in the other three regions can be detected when applying FU as the threshold variable.

Second, comparing the effects of the three economic variables on housing prices when under different regimes of macroeconomic and financial uncertainty, we see if macroeconomic uncertainty is low, or financial uncertainty is in the low or middle regime, the effect on the interest rate is negative, and the effects on both construction cost and economic activity are positive for most cases. These results agree with those of linear regression and the theoretical expectation. Conversely, when macroeconomic or financial uncertainty is high, housing demand and investment will be suppressed, causing a decline in housing prices and interest rates, while rising construction costs or economic activity could either reduce housing prices or not affect them at all.

Third, concerning the effects of the two uncertainty variables on housing prices under different macroeconomic uncertainty regimes, if macroeconomic risk is low, its effect is negative, while the effect of financial uncertainty is positive in most regions—the same as in the results of basic panel regression. Conversely, if macroeconomic risk becomes high, the effect of macroeconomic uncertainty will be insignificant in most regions, while the effect of financial uncertainty will be ambiguous and differentiated between regions.

Finally, comparing the effects of the two uncertainty variables on housing prices under different regimes of financial uncertainty, when under the middle regime, the effect of macroeconomic uncertainty will be negative, and that of financial uncertainty

Table 10 Tests for the number of EPU Threshold Effects

	Full sample	Midwest region	Northeast region	West region	South region
Single threshold					
*F*1	204.36	42.60*	39.61**	67.68***	57.79
P-Value	0.24	0.06	0.03	0.00	0.98
Double threshold					
*F*2		56.50***	34.51***	92.32***	
P-Value		0.00	0.00	0.00	
Triple threshold					
*F*3		25.15	26.32	25.05	
P-Value		0.11	0.40	0.92	

Notes: *** and ** indicate statistical significance at the 1, 5, and 10% levels, respectively will be positive for all regions, as shown by the results of basic panel regression. Note, the effect of both kinds of uncertainty is positive in the low regime and negative in the high regime for most of the regions.

The effects of MU and FU on regional housing prices are significant in most cases, implying the importance of macroeconomic and financial uncertainty modeling housing prices. Therefore, the role of MU and FU should be considered for housing policymakers and any housing investment participants. Especially, in the high financial uncertainty regime, both rising macroeconomic or financial uncertainty can cause a slump in housing prices. Therefore, housing investors should be aware of macroeconomic information and financial risk and adopt a more conservative investment

Table 11 Results of panel threshold regression by using EPU

Variable	Midwest region	Northeast region	West region
	EPU ≤ 2.1461	EPU ≤ 2.0374	EPU ≤. 2.0374
First regime (Low level)			
dLr	0.002	0.03***	0.04***
	(0.73)	(0.00)	(0.00)
dCONc	0.23***	0.31***	0.49***
	(0.00)	(0.00)	.00)
dECa	0.21***	0.23***	0.17***
	(0.00)	(0.00)	(0.00)
EPU	0.02**	−0.06***	−0.06***
	(0.01)	(0.00)	(0.00)
	2.1461 < EPU ≤ 2.1732	2.0374 < EPU ≤ 2.1523	2.0374 < EPU ≤ 2.1523
Second regime (Middle level)			
dLr	0.01	−0.04***	−0.02**
	(0.67)	(0.00)	(0.01)
dCONc	1.51***	0.37***	0.44***
	(0.00)	(0.00)	(0.00)
dECa	0.46**	0.23***	−0.40
	(0.01)	(0.00)	(0.51)
EPU	−1.51***	−0.02	0.10**
	(0.00)	(0.63)	(0.01)
	EPU > 2.1732	EPU > 2.1523	FU > 2.1523
Third regime (High level)			
dLr	−0.07***	−0.74***	−0.02
	(0.00)	(0.00)	(0.18)
dCONc	0.57***	0.62***	1.34***
	(0.00)	(0.00)	(0.00)
dECa	−0.12	−0.005	−0.30**
	(0.51)	(0.97)	(0.04)
EPU	0.01	0.03	0.11**
	(0.90)	(0.39)	(0.01)

Notes: *** and ** indicate statistical significance at the 1, 5, and 10% levels, respectively, and *t*-value is in brackets

Table 12 Test for the number of MU threshold effects in 12 cities

Region	City	Single threshold		Double threshold	
		Threshold Value ($r1$)	$F1$	Threshold Value ($r1$, $r2$)	$F2$
Midwest	Minneapolis	(0.79)	18.00*	(0.77, 0.85)	14.07
	Columbus	(0.87)	19.85*	(0.79, 0.85)	11.94
	Detroit	(0.75)	12.34		
Northeast	Boston	(0.75)	8.45		
	Newark	(0.79)	21.95*	(0.75, 0.77)	8.65
	Montgomery	(0.79)	24.60*	(0.75, 0.79)	10.48
West	Portland	(0.79)	32.94***	(0.79, 0.84)	15.12
	Oakland	(0.79)	17.23		
	Riverside	(0.77)	27.26***	(0.71, 0.77)	17.01
South	Austin	(0.79)	36.92***	(0.79, 0.84)	20.94
	Jacksonville	(0.77)	23.66*	(0.79, 0.84)	5.13
	Atlanta	(0.79)	28.54**	(0.79, 0.84)	19.30

Notes: $r1$ and $r2$ denote threshold estimates point where the likelihood ratio equal to zero, ***, **, and * indicate statistical significance at the 1, 5, and 10% levels, respectively

strategy if financial uncertainty reaches a high level. Policymakers should monitor changes in financial risk and timely apply policy tools to stabilize the financial system and reduce financial risk, which can avoid these economic uncertainties causing a downturn crisis in housing markets.

Appendix 1: Panel Threshold Regression using EPU as threshold variable

To examine the nonlinear effect of EPU on regional housing prices, panel threshold regression is employed to estimate Eq. (4) with EPU. Table 10 provides the statistics for $F1$, $F2$, and $F3$ and their bootstrap p-values using EPU as the threshold variable. As Table 10 shows, there are no threshold effects in the full sample and the South region and a double threshold effect in the other three regions. The results of panel threshold regression employing EPU as the threshold variable are displayed in Table 11. Comparing the results of Tables 6 and 9 by applying MU and FU as the threshold variable, in Table 11, the coefficients of dLr, dCONc, and dECa show similar results. The coefficients of EPU, for the first regime, are negative for the Northeast and West regions but positive in the Midwest region; for the second regime, the coefficients of EPU are significantly negative in the Midwest region and positive in the West region, while the coefficient is only significantly positive in the West region for the third regime. Hence, EPU has an ambiguous effect on different regional housing prices in the middle and high regimes.

Table 13 Result of threshold regression with MU threshold variable in 12 cities

Variable	Midwest		Northeast region		West region		South region		
	Minneapolis	Columbus	Newark	Montgomery	Portland	Riverside	Austin	Jacksonville	Atlanta
First regime (Low level)									
	MU < 0.79	MU < 0.87	MU < 0.79	MU < 0.79	MU < 0.79	MU < 0.77	MU < 0.79	MU < 0.77	MU < 0.79
dLr	−0.03	−0.01	0.01	0.01	−0.0001	0.04	−0.01	0.03	0.02
dCONc	0.35***	0.18	0.30**	0.26**	0.21**	0.29	−0.02	0.05	0.27**
dECa	0.20	0.26**	0.19*	0.19*	0.11	0.19	−0.07	0.16	0.14
MU	−0.22***	−0.13***	−0.08	−0.01	−0.12**	0.51**	−0.09	−0.04	−0.16**
FU	0.04 **	0.01	0.06**	0.02	−0.04**	−0.01	−0.02	0.003	0.01
Second regime (High level)									
	0.79 < MU	0.87 < MU	0.79 < MU	0.79 < MU	0.79 < MU	0.77 < MU	0.79 < MU	0.77 < MU	0.79 < MU
dLr	−0.03	0.31***	−0.06**	−0.04**	−0.07***	−0.02	−0.08**	−0.04 *	−0.07***
dCONc	0.45**	−0.27	0.40**	0.47***	0.07***	0.90***	0.51***	0.55 ***	0.53***
dECa	0.36*	−0.03	0.38**	0.43**	0.15	0.16	−0.002	0.25	0.13
MU	−0.27***	−0.17	0.18***	−0.08*	−0.04	0.25***	−0.06	−0.14 ***	−0.14 ***
FU	0.07***	0.08	0.02	0.0001	−0.08***	0.03	−0.001	−0.02	0.02

Notes: *** and ** indicate statistical significance at the 1, 5, and 10% levels, respectively, and t-value is in brackets

Table 14 Test for the number of FU threshold effects in 12 cities

Region	City	Single threshold		Double threshold		Triple threshold	
		Threshold value ($r1$)	$F1$	Threshold value ($r1$, $r2$)	$F2$	Threshold value ($r1$, $r2$, $r3$)	$F3$
Midwest	Minneapolis	(0.97)	26.27**	(0.97,1.13)	24.37*	(0.82, 0.98, 1.08)	15.75
	Columbus	(1.08)	56.64***	(0.90, 1.08)	38.96***	(0.86, 0.95, 1.07)	19.02
	Detroit	(1.02)	20.01*	(0.83, 1.02)	14.88	(0.83, 0.98, 1.09)	13.19
Northeast	Boston	(0.90)	14.53				
	Newark	(0.83)	39.93***	(0.83, 0.97)	25.10*	(0.83, 0.86, 0.97)	14.77
	Montgomery	(0.97)	27.94***	(0.83, 0.97)	30.86***	(0.83, 0.86, 0.98)	10.24
West	Portland	(0.86)	49.34***	(0.86, 0.96)	44.70***	(0.86, 0.93, 0.98)	14.84
	Oakland	(0.86)	48.98***	(0.86, 1.02)	36.58***	(0.86, 1.02, 1.14)	16.81
	Riverside	(0.86)	42.50***	(0.86, 1.04)	22.85*	(0.81, 0.95, 1.07)	11.65
South	Austin	(0.87)	48.74***	(0.87, 0,98)	40.29***	(0.87, 0.98, 1.08)	16.51
	Jacksonvile	(0.86)	35.85***	(0.86, 1.06)	31.29***	(0.78, 0.86, 1.06)	13.06
	Atlanta	(0.86)	37.53***	(0.86, 0.98)	33.16**	(0.83, 0.86, 0.98)	12.66

Notes: $r1$ and $r2$ denote threshold estimates point where the likelihood ratio equal to zero, ***, **, and * indicate statistical significance at the 1, 5, and 10% levels, respectively

Table 15 Result of threshold regression with FU threshold variable in 12 cities

Variable	Midwest			Northeast		West			South		
	Minneapolis	Columbus	Detroit	Newark	Montgomery	Portland	Oakland	Riverside	Austin	Jacksonvile	Atlanta
First regime											
	FU < 0.97	FU < 0.90	FU < 1.02	FU < 0.83	FU < 0.84	FU < 0.86	FU < 0.86	FU < 0.86	FU < 0.87	FU < 0.86	FU < 0.86
dLr	−0.02	−0.01	−0.02	−0.04**	−0.02	0.01	0.02	0.04	−0.01	0.02	0.02
dCONc	0.49***	0.08	0.50***	0.37**	0.31*	0.20*	0.46**	0.53***	0.04	0.16	0.22**
dECa	0.35***	0.28**	0.21	0.19*	0.19	0.14*	−0.12	0.15	−0.10	0.14	0.08
MU	−0.14***	−0.14***	−0.37***	0.10**	0.12**	0.07	0.05	0.19***	−0.03	0.11*	−0.07*
FU	0.01	0.14*	0.001	−0.04	−0.05	0.04	0.38***	0.38***	0.01	0.15**	0.13***
Second regime											
	0.97 < FU < 1.13	0.90 < FU < 1.08	1.02 < FU	0.83 < FU < 0.97	0.83 < FU < 0.98	0.86 < FU < 0.96	0.86 < FU < 1.02	0.86 < FU < 1.04	0.87 < FU < 0.98	0.86 < FU < 1.06	0.86 < FU < 0.98
dLr	0.11***	−0.04	−0.02	0.02	0.004	−0.04*	−0.02	0.04	−0.13***	−0.03	−0.05*
dCONc	0.32**	0.51***	−0.26	0.52***	0.48***	0.59***	0.84***	1.24***	0.54	0.65***	0.32**
dECa	0.11	0.12	0.15	0.65***	0.66***	0.35**	0.15	0.2	0.06	0.18	0.39***
MU	−0.19***	−0.19***	−0.26***	−0.01	0.03	−0.12**	−0.34***	−0.28***	−0.05	−0.18***	−0.17***
FU	0.38***	0.04	−0.09	−0.2***	−0.17***	−0.17**	−0.18*	−0.03	−0.45***	−0.07	−0.03***
Thirdregime											
	0.87 < FU	1.08 < FU		0.97 < FU	0.97 < FU	0.96 < FU	1.02 < FU	1.04 < FU	0.98 < FU	1.06 < FU	0.98 < FU
dLr	0.07	0.11*		0.04	0.05*	0.03	0.14***	0.03	0.05*	0.05	0.05*
dCONc	−0.82	0.15		0.02	0.10	0.20	0.00	−0.06	0.001	−0.11	0.16
dECa	−0.51	−0.08		0.05	0.05	−0.07	0.07	−0.01	−0.004	0.19	0.03
MU	−0.08	0.003		−0.26***	−0.12***	−0.17***	−0.31***	−0.26***	−0.09**	−0.19***	−0.18***
FU	−0.34	−0.17**		0.17***	0.10**	0.11***	0.1	0.05	0.04	0.01	0.07*

Notes: *** and ** indicate statistical significance at the 1, 5, and 10% levels, respectively, and *t*-value is in brackets

Appendix 2: The results of threshold regression by applying time series data of each city

This section applies threshold regression further examining the effect of MU and FU on the housing prices of individual cities. In each of the four regions, we execute the estimation of time series for three cities with the highest, medium, and lowest housing prices. The 12 cities are named as follows: (1) the Midwest region—Minneapolis, Columbus, and Detroit; (2) the Northeast region—Boston, Newark, and Montgomery; (3) the West region—Portland, Oakland, and Riverside; (4) the South region—Austin, Jacksonville, and Atlanta.

In Table 12, using MU as the threshold variable, except for Detroit, Boston, and Oakland, MU has a single-threshold effect on housing prices in the other nine cities, and the results of threshold regression for the nine cities are as Table 13. In Table 13, the coefficients of dLr, dCONc, and dECa in most of the cities show similar results based on the data of four regional housing prices (in Table 6). For both regimes, the coefficients of MU are negative in all nine cities, and the coefficient of FU is positive in most of the nine cities.

In Table 14, using FU as the threshold variable, there is no threshold effect in Boston and a double-threshold effect on housing prices in the other eleven cities, and then the results of threshold regression for the eleven cities are displayed in Table 15. Comparing with the coefficients of the three economic variables based on the data of four regional housing prices (in Table 9), these coefficients show similar results in Table 15. The effect of MU is negative for most cites in the three regimes, but positive in the first regime for the cities in the Northeast and West regions. The effect of FU is positive for most cities in the first and third regimes, but negative for most cities in the second regime.

References

Abel, A. B., & Eberly, J. C. (1999). The effects of irreversibility and uncertainty on capital accumulation. *Journal of Monetary Economics, 44*, 339–377.

Acharya, V., & Pedersen, L. (2005). Asset pricing with liquidity risk. *Journal of Financial Economics, 77*(2), 375–410. https://doi.org/10.1016/j.jfineco.2004.06.007

Adams, Z., & Füss, R. (2010). Macroeconomic determinants of international housing markets. *Journal of Housing Economics, 19*(1), 38–50.

Aye, G. C. (2018). Causality between economic policy uncertainty and real housing returns in emerging economies: A cross-sample validation approach. *Cogent Economics & Finance, 6*(1), 1–16. https://doi.org/10.1080/23322039.2018.1473708

Bahmani-Oskooee, M., & Ghodsi, S. H. (2017). Policy uncertainty and house prices in the United States. *Journal of Real Estate Portfolio Management, 23*(1), 73–85.

Bakas, D., & Triantafyllou, A. (2018). The impact of uncertainty shocks on the volatility of commodity prices. *Journal of International Money and Finance, 87*, 96–111. https://doi.org/10.1016/j.jimonfin.2018.06.001

Baker, S., Bloom, N., & Davis, S. (2016). Measuring economic policy uncertainty. *The Quarterly Journal of Economics, 131*, 1593–1636.

Balcilar, M., Roubaud, D., Uzuner, G. & Wohar, M. (2021). Housing and economic policy uncertainty in the OECD countries. *International Review of Economics & Finance, 76*(3). https://doi.org/10.13140/RG.2.2.35889.61286.

Bansal, R., & Yaron, A. (2004). Risks for the long run: A potential resolution of asset pricing puzzles. *The Journal of Finance, 59*(4), 1481–1509. https://doi.org/10.1111/j.1540-6261.2004.00670.x

Bardhan, A., Edelstein, R., & Tsang, D. (2007). Global financial integration and real estate security returns. *Real Estate Economics, 36*(2), 285–311.

Bernanke, B. S. (1983). Irreversibility, uncertainty, and cyclical investment. *The Quarterly Journal of Economics., 98*, 85–106.

Bhattacharya, S., Goodhart, C. A. E., Tsomocos, D. P., & Vardoulakis, A. P. (2015). A reconsideration of Minsky's financial instability hypothesis. *Journal of Money, Credit and Banking, 47*(5), 931–973. https://doi.org/10.1111/jmcb.12229
Caballero, R. (1991). On the sign of the investment-uncertainty relationship. *American Economic Review., 81*, 279–288.
Chien, M. S., & Setyowati, N. (2020). The effects of uncertainty shocks on global housing markets. *International Journal of Housing Markets and Analysis, 14*(1), 218–242.
Choudhry, T. (2020). Economic policy uncertainty and house prices: Evidence from geographical regions of England and Wales. *Real Estate Economics, 48*(2), 504–529.
Christidou, M., & Fountas, S. (2017). Uncertainty in the housing market: Evidence from US states. *Studies in Nonlinear Dynamics & Econometrics, 22*(2), 20160064. https://doi.org/10.1515/snde-2016-0064
Christou, C., Gupta, R., & Hassapis, C. (2017). Does economic policy uncertainty forecast real housing returns in a panel of OECD countries? A Bayesian approach. *The Quarterly Review of Economics and Finance, 65*, 50–60. https://doi.org/10.1016/j.qref.2017.01.002
Christou, C., & Gupta, R., & Nyakabawo, W. (2019). Time-varying impact of uncertainty shocks on the US housing market. *Economics Letters*, Elsevier, 180(C), 15–20.
Craine, R. (1989). Risky business: The allocation of capital. *Journal of Monetary Economics., 23*, 210–218.
Di Pasquale, D., & Wheaton, W. (1994). Housing market dynamics and the future of housing prices. *Journal of Urban Economics, 35*, 1–27. https://doi.org/10.1006/juec.1994.1001
Dorofeenko, V., Lee, G. S., & Salyer, K. D. (2014). Risk shocks and housing supply: A quantitative analysis. *Journal of Economic Dynamics and Control, 45*, 194–219.
El-Montasser, G., Ajmi, A. N., Chang, T., Simo-Kengne, B. D., Andre, C., & Gupta, R. (2016). Cross-country evidence on the causal relationship between policy uncertainty and housing pricess. *Journal of Housing Research, 25*(2), 195–211.
Grum, B., & Govekar, D. K. (2016). Influence of macroeconomic factors on prices of real estate in various cultural environments: Case of Slovenia, Greece, France, Poland and Norway. *Procedia Economics and Finance, 39*, 597–604. https://doi.org/10.1016/s2212-5671(16)30304-5
Gupta, R., Lau, C. K. M., Plakandaras, V., & Wong, W. K. (2019). The role of housing sentiment in forecasting U.S. home sales growth: evidence from a Bayesian compressed vector autoregressive model. *Economic Research-Ekonomska Istraživanja,* 32(1), 2554–2567. https://doi.org/10.1080/1331677x.2019.1650657
Gyourko, J., & Saiz, A. (2006). Construction costs and the supply of housing structure. *Journal of Regional Science, 46*(4), 661–680. https://doi.org/10.1111/j.1467-9787.2006.00472.x
Han, L. (2008). Hedging housing prices risk in the presence of lumpy transaction costs. *Journal of Urban Economics, 64*(2), 270–287. https://doi.org/10.1016/j.jue.2008.01.002
Hansen, B. E. (1999). Threshold effects in non-dynamic panels: Estimation, testing, and inference. *Journal of Econometrics, 93*(2), 345–368. https://doi.org/10.1016/s0304-4076(99)00025-1
Harris, J. (1989). The effect of real rate of interest rate on housing prices. *Journal of Real Estate, Finance, and Economics, 2*(1), 47–60.
Jinjarak, Y., & Sheffrin, S. M. (2011). Causality, real estate prices, and the current account. *Journal of Macroeconomics, 33*(2), 233–246. https://doi.org/10.1016/j.jmacro.2010.11.001
Jurado, K., Ludvigson, S. C., & Ng, S. (2015). Measuring Uncertainty. *American Economic Review, 105*(3), 1177–1216.
Levin, E. J., & Pryce, G. B. J. (2009). What determines the price elasticity of house supply? Real interest rate effects and cyclical asymmetries. *Housing Studies, 24*(6), 713–736. https://doi.org/10.1080/02673030903215860
McCarthy, J., & Peach, R. W. (2004). Are home prices the next bubble? *Federal Reserve Bank of New York Economic Policy Review, 10*(3), 1–17.
Minsky, H. P. (1980). A theory of systemic fragility, Hyman P. Minsky Archive. 231.
Strobel, J., Nguyen Thanh, B., & Lee, G. (2020). Effects of macroeconomic uncertainty and labor demand shocks on the housing market. *Real Estate Economics, 48*(2), 345–372.

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