# Regimes dependent speculative trading: evidence from the United States housing market

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This paper investigates the U.S. housing price dynamics from the perspective of speculative trading, in addition to the macro-finance factors such as the stock market, household disposable income and nominal interest rate. It is found that among the speculative investors, fundamental traders drive house price away from the fundamental value. Their trading is weakened in the regime of high nominal interest rate and their behavior even changes to push the price towards the fundamental value when price deviation is large. A second type of speculative traders is momentum traders who believe that the trend of the recent price movement would be persistent. Stock market has a positive effect on the house price. The positive effect of household income becomes pronounced when nominal interest rate is high. When the nominal interest rate is high, house price faces a negative effect from the nominal interest rate and the positive effect of inflation disappears. Among all the factors, speculative trading is the largest market force driving the U.S. housing market which exhibits self-correction in the long run.

**Keywords**: Speculative trading; U.S. housing market; Wealth effect; Money illusion effect

**JEL Classifications**: C2; C5; E2; R2

# 1. INTRODUCTION

Housing market is one of the most important markets in our daily life. It accounts the major component of the wealth as well as transactions of the household. One of the triggering factors for the 2008 global crisis was the plummeting of the U.S. housing market. This paper investigates the dynamics of the U.S. housing market by looking at the speculative investment activities, in addition to the macro-finance factors including the stock market, household disposable income, nominal interest rate and inflation. It is found that these factors have regime dependent effects with respect to the nominal interest rate and with respect to the price deviation from fundamental value. The different regimes are captured by regression models using either dummy variables or a Smooth Transition Autoregression (STAR).

The extant literature mainly investigates the housing market from the perspectives of macro-finance factors. Ortalo-Magne and Rady (2006) develop a theoretical model to study the effect of income on the housing market. An increase in income has a positive effect on the house price and housing transactions. Brunnermeier and Julliard (2008) study the money illusion phenomenon in the housing market and find that inflation and nominal interest rate contribute to part of the price dynamics of the housing market. Goodhart and Hofmann (2008) find evidence of linkages among house price, monetary and macroeconomic variables. Nneji et al. (2013) report empirical finding from the U.S. housing market. The house price receives a positive effect from disposable income and a negative one from inflation. The significance and the magnitude of these effects also depend on the steady-state and boom regimes. Iacoviello and Minetti (2008) investigate the credit channel of monetary policy in the housing market. Ling and Naranjo (1999) report evidence of integration between the housing market and the stock market. Okunev et al. (2002) find a strong unidirectional influence from stock market to the housing market of Australia. Taking the stock market into account, Antonakakis and Floros (2016) examine the dynamic relationships among the housing market, the stock market and the macroeconomic variables in the U.K..

Besides the function of accommodation, housing market also has an investment function. As an investor can choose to rent or to own a housing property, a well developed rental market can foster speculative trading in housing market. If housing market is over-priced, a housing investor can sell his house and enter the rental market. In contrast, if housing market is under-priced, a renter would prefer to purchase a house, not to mention that a house owner also has willingness to purchase more houses to capture the excess profit. With this reasoning, the aspect of investment or speculative trading should be taken into account for the housing market. Malpezzi and Wachter (2005) demonstrate that subject to elasticity of supply, speculative trading featured with serial correlation of price contributes to boom and bust cycles in a housing market. Sommervoll et al. (2010) simulate house price dynamics based on a heterogeneous agents model consisting of buyers, sellers and mortgagees. They demonstrate that credit constraint increases price volatility. Dieci and Westerhoff (2012) develop a theoretical model for the housing market featured with speculative trading by extrapolative and regressive forecasting rules. Dieci and Westerhoff (2013) further investigate different theoretical setups of trader behaviors and market structures. Kouwenberg and Zwinkels (2014) report empirical evidence of heterogeneous speculative trading in U.S. housing market. The heterogeneous speculating trading consists of momentum trading by chartists and trading of reversal to fundamental value by fundamentalists. In investigating eight different countries, Bolt et al. (2014) also find similar evidence of heterogeneous agents in the housing market with respect to the fundamental value: mean-reversion towards and further diverting from the fundamental value. Nathanson and Zwick (2014) investigate the speculation in the housing market from the aspect of land market by developing a model consisting of heterogeneous beliefs about future house prices.

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As both macro-finance and speculative trading variables explain the dynamics of the housing market, regressions on either macro-finance variables or speculative trading ones may suffer from missing variables and cause devastating effect to their inference. This paper include macro-finance as well as speculative trading variables as explanatory variables and assess their capability in explaining the price dynamics. We further determine which variables are the key factors in driving the price dynamics. It is found that the variables have regime-dependent effects with respect to different regimes of nominal interest rate and price deviation. We find momentum (Case and Shiller, 1989) and mean reversion (Cutler et al., 1991) trading which instead exhibit regime-dependent behaviors in our results. We also find evidence of money illusion effect as reported by Brunnermeier and Julliard (2008). Our results further shed some light on this money illusion phenomenon by showing that it is also regime dependent. The U.S. housing market exhibits certain market efficiency in the sense that the house price diverts from fundamental value in the short run and reverses to the fundamental in the long run. Overall, speculative trading has a dominant role in the price dynamics of U.S. housing market.

The rest of the paper is organized as follows. Section 2 introduces the empirical model incorporating both speculative trading and macro-finance variables. In Section 3 we introduce the data used in this paper. Section 4 reports the estimation results. In Section 5 we further investigate the regime-dependent behaviors with respect to price deviation. Finally, Section 6 concludes.

[1] Indeed, speculative trading encompassing heterogeneous strategies has been intensively studied in financial markets. De Long et al. (1990) and De Long et al. (1991) prove the survival of noise traders. Boswijk et al. (2007) and Chiarella et al. (2012) find evidence of behavioral heterogeneity in stock markets. Reitz and Taylor (2008) report heterogeneity of traders in foreign exchange markets. Based on a framework of heterogeneous traders, Alfarano et al. (2008) develop analytical solutions for the typical stylized facts of financial markets such as fat-tails and time-variation of higher moments. Ghonghadze and Lux (2016) further develop a GMM estimator for the typical stylized facts and apply it for estimation of a range of financial markets. For more details, we cite, in particular, Day and Huang (1990), Lux (1995), De Grauwe et al. (1995), Block and Hommes (1997, 1998), and Chiarella and He (2002).

## 2. EMPIRICAL MODEL

In a housing market, price and rental fee per unit house at period $t$ are $P_t$ and $Q_t$. Taking into account of normal practice that rents are usually paid at the beginning of each period, $Q_t$ in terms of currency at $t+1$ is expressed as $\left(1+r^f\right)Q_t$, where $r^f$ is the risk free rate. Fundamental value $F_t$ is derived from the discounted future cash flows according to

$$F_t = E\left[\frac{P_{t+1} + \left(1+r^f\right)Q_t}{1+r}\right],$$

where $r$ is the discount factor. With an unbiased expectation, the expected future price should be equal to the future fundamental value, that is $E\left[P_{t+1}\right] = E\left[F_{t+1}\right]$. Hence,

$$F_t = \frac{E\left[F_{t+1}\right] + \left(1+r^f\right)Q_t}{1+r}.$$

Assume the average growth rate of the rent is $g$, we have $Q_{t+1} = (1+g)\,Q_t$. With iterated substitution for the fundamental values, we get

$$\begin{aligned} F_t &= \frac{\left(1+r^f\right)Q_t}{r-g} \\ &= R \cdot Q_t, \end{aligned} \tag{1}$$

where $R = \left(1+r^f\right)/(r-g) = F_t/Q_t$. Following Bolt et al. (2014), we approximate $R$ based on the mean rental yield or the average of $Q_t/P_t$:

$$\begin{aligned} \frac{1}{R} &= ave\left(\frac{Q_t}{F_t}\right) \\ &\approx ave\left(\frac{Q_t}{P_t}\right). \end{aligned}$$

Given the fundamental value $F_t$, price deviation from fundamental at period $t$, $x_t$, is defined as

$$x_t = P_t - F_t. \tag{2}$$

Relying on the latest information of price deviation $x_{t-1}$, fundamental traders in the housing market contribute to the price dynamics $\Delta P_t = P_t - P_{t-1}$ by $c_f \cdot x_{t-1}$, where

$c_f$ is a fundamental demand coefficient. A negative $c_f$ indicates that fundamental traders purchase when the housing market is under-valued and sell when it is over-valued. Through this process, fundamental traders drive the house price to the fundamental value. In contrast, a positive $c_f$ means fundamental traders behave in a contrary way and therefore push the house price further away from the fundamental value.

Besides fundamental traders, there are other traders active in the housing market, such as chartists. Instead of the fundamental value, chartists rely on historical price movements to make their investment decision. As chartists are myopic, the latest price change $\Delta P_{t-1}$ is taken into account. The contribution of chartists to the price dynamics is captured by $c_c \cdot \Delta P_{t-1}$ with $c_c$ a chartist coefficient. A negative $c_c$ suggests that chartists move against the past price movement with mean-reversion trading and tend to stabilize the price dynamics. On the other hand, a positive $c_c$ indicates that chartists believe in a persistent trend of the price and then trade in a manner of momentum trading.

In addition to the trading behaviors of the housing market players, we control variables related to the macro-finance factors. The first factor is the stock market return at period $t$, $r_t^{st}$ which captures any potential wealth effect from the financial markets to the housing market. The second factor we consider is the personal disposable income $y_t$. The increment of the disposable income $\Delta y_t$ is supposed to have a positive effect on the house price. The third factor is the nominal interest rate $i_t$. The recent change of nominal interest rate $\Delta i_{t-1}$ is utilized to investigate the effect of nominal interest rate on the housing market. The last factor is the inflation rate $\pi_t$. The latest inflation rate $\pi_{t-1}$ is adopted as a regressor. The usage of nominal interest rate and inflation rate is inspired by Brunnermeier and Julliard (2008) to take into account of any potential money illusion phenomenon which is defined in the way that market participants cannot take into account of inflation properly and therefore a reduction in inflation causes an increase in house price, i.e. a negative effect from inflation. The reason of using nominal interest rate and inflation rate at $t-1$, instead of $t$ is due to the potential reversed bias as shown in the sequel causality test.

Adding up all the variables leads to a linear model for the price dynamics of the housing market:

$$\begin{cases} \Delta P_t = \beta_0' \cdot X_t + u_t, \\ u_t = \varepsilon_t \sqrt{h_t}, \\ h_t = \alpha_0 + \alpha_1 u_t^2 + \alpha_2 h_{t-1} + \alpha_3 h_{t-2}. \end{cases} \quad (3)$$

where $X_t$ is a vector consisting of the price deviation $x_{t-1}$, past price change $\Delta P_{t-1}$, return of the stock market $r_t^{st}$, change of the personal disposed income $\Delta y_t$, the recent change of nominal interest rate $\Delta i_{t-1}$ and the recent inflation rate $\pi_{t-1}$. $\beta_0$ is the corresponding column vector of coefficients and $'$ indicates a transpose operator. The variance process $h_t$ follows a standard GARCH(2, 1) model to capture the heteroscedasticity.[2]

Since the nominal interest rate is an important policy tool affecting the housing market, investigating potential variant behaviors of the housing market under regimes of low and high nominal interest rates should be beneficial to the thorough understanding on the effect of nominal interest rate. This is in a similar spirit to the market uncertainty in the finding of Connolly et al. (2005) that the correlation between stock and bond returns has different behaviors under low and high market uncertainty. To differentiate the regimes of low and high nominal interest rates, we generate a dummy variable $dum_t^i$ based on the latest nominal interest rate $i_{t-1}$:

$$dum_t^i = \begin{cases} 1, \text{ if } i_{t-1} \geq c^i \\ 0, \text{ if } i_{t-1} < c^i \end{cases} . \quad (4)$$

$c^i$ is the threshold value of the nominal interest rate marking the boundary between the low and high nominal interest rate regimes. The variance equation does not

[2] Information criteria AIC, BIC and HQC all favor the GARCH(2,1) setting.

change while the mean equation of $\Delta P_t$ becomes

$$\Delta P_t = \beta_0' \cdot X_t + \beta_1' \cdot X_t \cdot dum_t^i + u_t, \tag{5}$$

where $\beta_1$ measures the behavioral changes of the explanatory variables in the environment of high nominal interest rate. In case the two regimes of nominal interest rate are significant, a Smooth Transition Autoregression (STAR) model is adopted as a robustness check. STAR also manages to capture the smooth transition between the two regimes to get a more accurate estimation result. The corresponding mean equation changes into

$$\Delta P_t = \beta_0' \cdot X_t + \beta_1' \cdot X_t \cdot g\left(i_{t-1}; \gamma^i, c^i\right) + u_t, \tag{6}$$

where the transition function $g\left(i_{t-1}; \gamma^i, c^i\right)$ is defined as

$$g\left(i_{t-1}; \gamma^i, c^i\right) = \left[1 + \exp\left(-\gamma^i\left(i_{t-1} - c^i\right)\right)\right]^{-1}.$$

$g\left(i_{t-1}; \gamma^i, c^i\right)$ is bounded between 0 and 1. $\gamma^i$ is the transition parameter measuring the speed of transition between regimes. $c^i$ is the threshold value to be estimated. $g\left(i_{t-1}; \gamma^i, c^i\right)$ is an increasing function with $i_{t-1}$ given a positive $\gamma^i$ and the converse happens if $\gamma^i$ is negative. $\beta_1$ still measures the interaction effect in the regime determined by $g\left(i_{t-1}; \gamma^i, c^i\right)$.

## 3. DATA

We obtain the U.S. quarterly data with sample period 1975Q4 - 2015Q3 from Datastream. The data include the residential property price index, non-farm housing rental index, DJIA stock index, disposable personal income, nominal interest rate represented by 3-month Treasury bills, and CPI index. All variables except the nominal interest rate are deflated by the CPI to get the real terms. Note that house price and rent are in index form, instead of actual values. To derive the actual rental yield $Q_t/P_t$, we calibrate the rental index by observed rental yield at a particular period. According to Bolt et al. (2014), the actual rental yield from the U.S. at 2013Q1 is 4.29%. As the corresponding non-calibrated rental yield of our data at that particular quarter is 64.30%, we obtain a calibrating scalar equal to 0.0667. Therefore, our rental index is calibrated by multiplying the scalar 0.0667 to produce the desired time series $Q_t$ upon which we derive the time series of fundamental value using e.q. (1). We also calculate the quarterly return of the stock market $r_t^{st}$ and inflation rate $\pi_t$ from the DJIA index and CPI respectively.

Fig. 1 shows the time series of all variables. There is a breaking point of the U.S. housing market in 1998, before and after which the housing market is under- and over-valued. The housing price rises dramatically since 1996, reaches the peak of a bubble in 2005, hits the bottom during the subprime crisis and then rebounds, resulting in an increasing price deviation from then on. Another observation from Fig. 1 is the persistent trends in the housing market, especially the rising trend between 1996 and 2005, as well as the decreasing one between 2005 and 2010. The DJIA stock index increases continuously from 1980s to the end of 1990s. After 2000, the stock market remains at elevated levels with two plummeting events of the burst of 'dot com bubble' and the subprime crisis. During the whole sample period, personal disposable income continues to increase most of the time except in the period of the subprime crisis; the nominal interest rate has a decreasing trend from the beginning of 1980s; and the inflation rate is stable with positive mild values except some positive spikes at the end of the 1970s and some negative spikes during the subprime crisis.

## 4. ESTIMATION RESULTS

Before we start the regressions, we first check the causality relationships among the variables. As shown in Table 1, price change $\Delta P$ Granger-causes change of

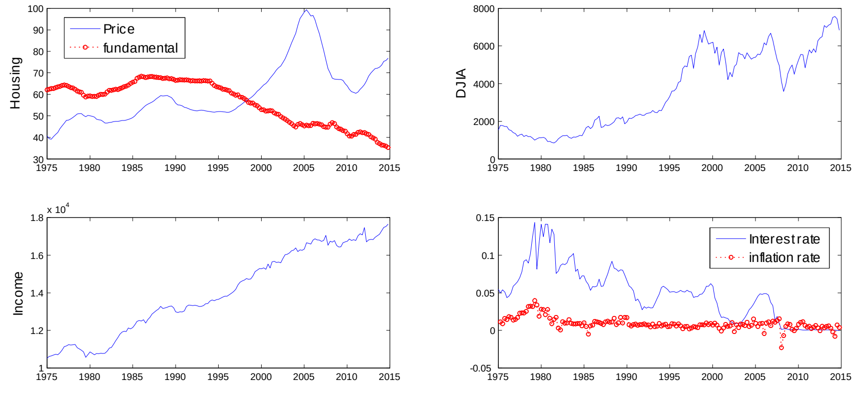


**FIG. 1** Time series of housing price, fundamental value, DJIA, disposable income, interest rate and inflation rate.

nominal interest rate $\Delta i$. Although the Granger-causality from $\Delta P$ to inflation rate $\pi$ is statistically insignificant, the p-value is near to 10%. Therefore, there might be a concern of reversed bias in regressing $\Delta P_t$ on $\Delta i_t$ and $\pi_t$. The remedy is to use the lagged variables $\Delta i_{t-1}$ and $\pi_{t-1}$ in the subsequent regressions.

As the assumption of conditional normality is not satisfied, a heteroscedasticity consistent covariance is adopted in estimating each GARCH form model with maximum likelihood estimation. We first estimate the linear model without differentiating the regimes of low and high nominal interest rate. As reported in Table 2, the coefficient of $x_{t-1}$ is insignificant and positive, indicating that fundamental traders push prices away from the fundamental value, instead of driving it towards the fundamental value. The coefficient of $\Delta P_{t-1}$ is significant with a positive value. Chartists traders follow a momentum trading strategy to contribute to the persistent trend of the house price. There is a wealth effect transmitting from the stock market to the housing market as the coefficient of $r_t^{st}$ is significantly positive. The movements of the stock market have a simultaneous effect on the housing market. Another wealth effect arises from the change of personal disposable income $\Delta y_t$

TABLE 1
Granger causality tests.

| | | | |
|---|---|---|---|
| $\Delta P \to r^{st}$ | $\Delta P \to \Delta y$ | $\Delta P \to \Delta i$ | $\Delta P \to \pi$ |
| 1.961 | 5.075 | 10.714** | 8.726 |
| (0.743) | (0.280) | (0.030) | (0.121) |
| $r^{st} \to \Delta P$ | $\Delta y \to \Delta P$ | $\Delta i \to \Delta P$ | $\pi \to \Delta P$ |
| 5.581 | 12.169** | 5.593 | 12.381** |
| (0.233) | (0.016) | (0.232) | (0.030) |

Note: The table reports Wald test statistics for Granger causality. $\Delta P$, $r^{st}$, $\Delta y$, $\Delta i$, and $\pi$ denote change of house price, return of stock market, change of disposable income, change of nominal interest rate and inflation rate, respectively. P-values are in parenthesis. *, **, and *** denote significance at 10%, 5% and 1%.

which also has a significantly positive coefficient. For the effect of the change of nominal interest rate on the house price, the coefficient of $\Delta i_{t-1}$ is significantly negative, implying that an increase (decrease) of nominal interest rate has a negative (positive) effect on the house price in the next quarter. Inflation seems to have insignificant effect on the housing market. The GARCH process is significant.

To investigate any potential regime dependent behaviors with respect to the nominal interest rate, we introduce a dummy variable for nominal interest rate, $dum_t^i$, to indicate the regime with high nominal interest rate and to explore any interaction effect from the explanatory variables. The threshold value of nominal interest rate $c^i$ is determined by grid search. The regression model is named as linear+dummy whose results are reported in Table 2. For the linear component, coefficients of $r_t^{st}$, $\Delta y_t$ and $\Delta i_{t-1}$ become insignificant. However, coefficient of inflation $\pi_{t-1}$ becomes significant with a positive value, indicating that an increase in CPI has a positive effect on house price in the next quarter. In the regime of high nominal interest rate larger than the threshold value $c^i = 2.3\%$, the coefficient of the interaction effect of inflation is also significant but with a negative value which cancels the effect from the linear component. As a result, when the nominal interest rate is high, inflation has an overall negative effect on the housing price, indicating that money illusion prevails only in the regime of high nominal interest rate. The significance of the inflation in the regime of high nominal interest rate highlights the existence of different regimes of the nominal interest rate. To have a more accurate understanding on the effect of explanatory variables in different regimes of nominal interest rates, a STAR estimation is conducted with a feature of smooth transition between the two regimes. It has almost the same result as the linear model except some arising interaction effects in the regime of low nominal interest rate. As the transition parameter $\gamma^i$ is negative, the nonlinear component captures the interaction effect of the regressors in the regime of low nominal interest rate when the interest rate is below the threshold value $c^i = 2.6\%$. The interaction effect of $\Delta y_t$ is negative. The positive effect of disposable income is weakened in the regime of low nominal interest rate compared to the regime of high nominal interest rate. The interaction effect of $\pi_{t-1}$ is positive, making the net effect of inflation positive in the low nominal interest rate regime and insignificant in the high nominal interest rate regime. In the regime of high nominal interest rate, the effect of $\Delta i_{t-1}$ is mainly from the linear component with a significantly negative coefficient. Note that the transition parameter $\gamma^i$ appears to be insignificant. However, we should not be bothered by this result as the likelihood ratio test for $\gamma^i$ is significant. This seemingly insignificant transition parameter $\gamma^i$ is quite common for the STAR models as discussed in Terasvirta (1994).

## 5. REGIMES OF PRICE DEVIATION

In the regression models reported in Table 2, fundamental traders are not found in the three models as coefficients of $x_{t-1}$ are insignificant. In these models, we have assumed that trading strength of traders does not change with the magnitude of

TABLE 2

Parameter estimates for price changes of U.S. housing market.

| | linear model | | linear+dummy | | STAR | |
|---|---|---|---|---|---|---|
| | Coeff | s.e. | Coeff | s.e. | Coeff | s.e. |
| $x_{t-1}$ | 0.001 | (0.002) | 0.000 | (0.005) | 0.001 | (0.002) |
| $\Delta P_{t-1}$ | 0.880*** | (0.041) | 0.895*** | (0.050) | 0.836*** | (0.045) |
| $r_t^{st}$ | 0.685** | (0.315) | 0.184 | (0.969) | 0.881*** | (0.239) |
| $\Delta y_t$ | 8.544** | (3.626) | 2.848 | (7.853) | 13.043*** | (3.033) |
| $\Delta i_{t-1}$ | -10.105*** | (2.279) | 42.955 | (38.416) | -9.938*** | (1.895) |
| $\pi_{t-1}$ | 1.766 | (2.753) | 46.344*** | (15.704) | -1.828 | (2.687) |
| | | | Interest rate dummy | | Interest rate nonlinear part | |
| $x_{t-1}$ | | | 0.002 | (0.006) | -0.002 | (0.005) |
| $\Delta P_{t-1}$ | | | -0.055 | (0.064) | 0.075 | (0.070) |
| $r_t^{st}$ | | | 0.749 | (1.002) | -0.638 | (0.930) |
| $\Delta y_t$ | | | 9.995 | (8.204) | -12.722* | (6.737) |
| $\Delta i_{t-1}$ | | | -52.999 | (38.571) | 21.652 | (19.878) |
| $\pi_{t-1}$ | | | -47.648*** | (15.773) | 49.746*** | (13.700) |
| $\gamma^i$ | | | | | -1768 | 135421 |
| $c^i$ | | | 2.3% | | 2.6% | (12.5%) |
| | GARCH | | GARCH | | GARCH | |
| $\alpha_0$ | 0.002* | (0.001) | 0.002*** | (0.001) | 0.002*** | (0.000) |
| $\alpha_1$ | 0.096*** | (0.017) | 0.098*** | (0.025) | 0.100*** | (0.026) |
| $\alpha_2$ | 1.639*** | (0.039) | 1.679*** | (0.049) | 1.676*** | (0.046) |
| $\alpha_3$ | -0.730*** | (0.035) | -0.778*** | (0.041) | -0.774*** | (0.035) |
| LLh | -78.870 | | -69.186 | | -69.909 | |
| LRT | | | | | 0.000 | |

Note: The sample contains quarter observations from 1975Q4 to 2015Q3. Standard errors are in the parentheses. *, **, and *** denote significance at 10%, 5% and 1%. LLh is the log likelihood value, and LRT the p-value of likelihood ratio test with restriction $\gamma^i = 0$.

price deviation. However, financial markets have shown evidence that the demand strength of traders changes with the magnitude of price deviation. Menkhoff et al. (2009) report that expectation heterogeneity in foreign exchange rates decreases with increasing price deviation from the fundamental. In their research for the housing market, Bolt et al. (2014) find that the market influences of fundamental and chartist traders are time-varying.

To investigate the parameter constancy with respect to the price deviation, we include another dummy variable to indicate the regime of high price deviation $dum_t^x$ based on the absolute price deviation in the recent period $|x_{t-1}|$:

$$dum_t^x = \begin{cases} 1, \text{ if } |x_{t-1}| \geq c^x \\ 0, \text{ if } |x_{t-1}| < c^x \end{cases} . \tag{7}$$

where $c^x$ is the threshold value of the magnitude of the price deviation and it is also determined by grid search. We use $dum_t^x$ to investigate the interaction effect of the trading strength of the two types of traders. The mean equation of $\Delta P_t$ becomes

$$\Delta P_t = \beta_0' \cdot X_t + \beta_1' \cdot X_t \cdot dum_t^i + \beta_2' \cdot Y_t \cdot dum_t^x + u_t, \tag{8}$$

where the vector $Y_t$ consists of $x_{t-1}$ and $\Delta P_{t-1}$. We name this regression model as linear+dummy-2 whose estimation results are reported in Table 3. The estimated coefficients for the linear component are qualitatively the same as those of the linear+dummy model of Table 2 except for the coefficient of $x_{t-1}$ which turns into significant with a positive value, suggesting the deviation enlargement by the trading of fundamental traders. Looking at the interaction effect in the regime of high nominal interest with $c^i = 4.9\%$, the deviation enlargement of fundamental traders is weakened. Positive wealth effects of stock market and disposable income become significant. Nominal interest rate also starts to have a negative effect on the housing price. The inflation rate has a negative effect and makes the net effect of inflation changes from positive in regime of low nominal interest rate into an overall negative one in the regime of high nominal interest rate. In addition, for the interaction effect in the regime of high price deviation with $c^x = 20.549$, coefficient of $x_{t-1}$ is significantly negative with magnitude larger than the one in the linear component. That is, even if the nominal interest rate is low, when price deviation is high, the net effect of fundamental trader is negative and tends to drive the price towards the fundamental value.

From the regression model of linear+dummy-2, the differentiation of the regimes of price deviation turns all the variables into significant. To better capture the regimes switching, we also include a second STAR component with respect to price deviation into e.q. (6) and name the regression model as STAR-2.

$$\Delta P_t = \beta_0' \cdot X_t + \beta_1' \cdot X_t \cdot g\left(i_{t-1}; \gamma^i, c^i\right) + \beta_2' \cdot Y_t \cdot g\left(|x_{t-1}|; \gamma^x, c^x\right) + u_t, \quad (9)$$

where the transition function $g\left(|x_{t-1}|; \gamma^x, c^x\right)$ is defined as

$$g\left(|x_{t-1}|; \gamma^x, c^x\right) = \left[1 + \exp\left(-\gamma^x\left(|x_{t-1}| - c^x\right)\right)\right]^{-1}.$$

Table 3 reports the regression results of STAR-2 which are similar to the ones of STAR in Table 2. One of the differences is that the coefficient of $x_{t-1}$ of the linear component becomes significant too. For the nonlinear component with respect to the nominal interest rate, $\gamma^i$ is negative and therefore this nonlinear component imposes an interaction effect when nominal interest rate is low as marked by $c^i = 3.1\%$. This interaction effect in the regime of low nominal interest rate is highlighted in Fig. 2 which shows the transition function with respect to nominal interest rate. In the regime of low nominal interest rate, deviation enlargement of fundamental traders is enhanced. Momentum trading of chartist is also reinforced. Positive wealth effect from disposable income is changed into negative. The negative effect of nominal interest rate is changed into a positive one. That is, the net effect of nominal interest rate increment on the housing price is positive when the nominal interest rate is low, and changes into negative when the nominal interest rate is high. Inflation is only significant with a positive value given a low level of nominal

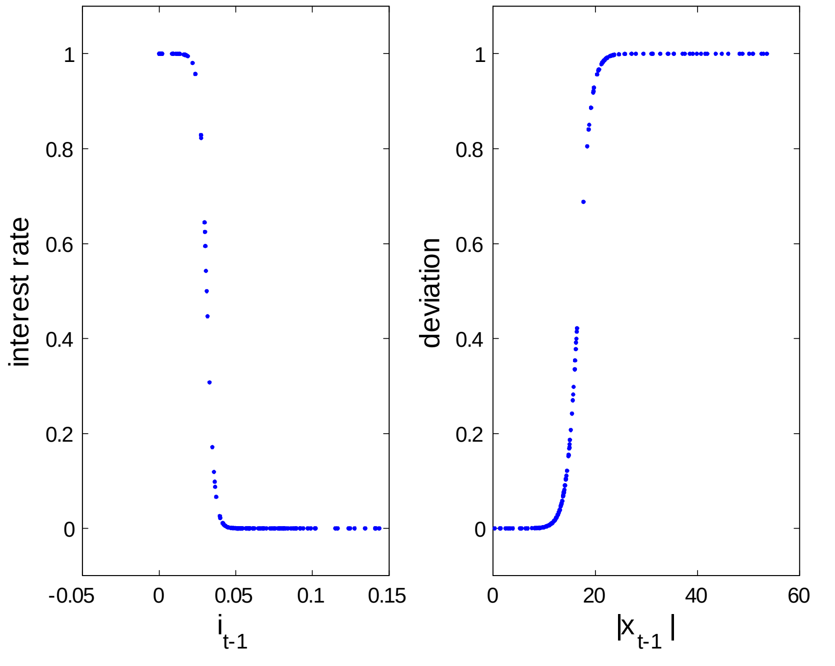


**FIG. 2** Plots of transitional functions. The left panel shows the transition function using interest rate as transition variable. The right panel shows the transition function using magnitude of price deviation as transition variable.

interest rate. Regarding the regimes of price deviation, the second nonlinear component comes into play when price deviation is large, as illustrated by the transition function with respect to price deviation in Fig. 2. When price deviation is large, the coefficient of the interaction effect of $x_{t-1}$ is negative. Fundamental traders change their trading style into the one of driving price towards the fundamental value, regardless of the level of nominal interest rate. The estimation results of STAR-2 are qualitatively the same as the ones of linear+dummy-2.

Based on the estimated STAR model reported in Table 3, Fig. 3 highlights different regimes in the U.S. housing market. The regime of low nominal interest rate mainly cover the periods after 2000 interrupted by the subprime crisis. The

TABLE 3

Parameter estimates for price changes of U.S. housing market with consideration of different regimes of nominal interest rate and price deviation.

| | linear+dummy-2 | | STAR-2 | |
|---|---|---|---|---|
| | Coeff | s.e. | Coeff | s.e. |
| $x_{t-1}$ | 0.023*** | (0.004) | 0.011*** | (0.004) |
| $\Delta P_{t-1}$ | 0.698*** | (0.092) | 0.789*** | (0.046) |
| $r_t^{st}$ | 0.042 | (0.480) | 1.000*** | (0.244) |
| $\Delta y_t$ | 4.289 | (3.014) | 16.490*** | (2.923) |
| $\Delta i_{t-1}$ | 0.648 | (5.907) | -7.646*** | (1.559) |
| $\pi_{t-1}$ | 31.821*** | (5.711) | 3.344 | (2.849) |
| | Interest rate dummy | | Interest rate nonlinear part | |
| $x_{t-1}$ | -0.018*** | (0.005) | 0.017*** | (0.004) |
| $\Delta P_{t-1}$ | 0.149 | (0.098) | 0.138* | (0.077) |
| $r_t^{st}$ | 1.109* | (0.577) | -0.023 | (0.769) |
| $\Delta y_t$ | 9.589** | (4.297) | -18.164*** | (6.613) |
| $\Delta i_{t-1}$ | -12.078* | (6.723) | 35.098** | (15.358) |
| $\pi_{t-1}$ | -34.395*** | (6.194) | 42.674*** | (8.241) |
| $\gamma^i$ | | | -426 | (541) |
| $c^i$ | 4.9% | | 3.1%*** | (0.3%) |
| | Deviation dummy | | Deviation nonlinear part | |
| $x_{t-1}$ | -0.026*** | (0.004) | -0.029*** | (0.005) |
| $\Delta P_{t-1}$ | 0.166* | (0.087) | -0.081 | (0.083) |
| $\gamma^x$ | | | 0.857* | (0.518) |
| $c^x$ | 20.549 | | 16.772*** | (0.772) |
| | GARCH | | GARCH | |
| $\alpha_0$ | 0.003*** | (0.001) | 0.002*** | (0.000) |
| $\alpha_1$ | 0.075*** | (0.014) | 0.084*** | (0.022) |
| $\alpha_2$ | 1.803*** | (0.034) | 1.791*** | (0.041) |
| $\alpha_3$ | -0.885*** | (0.030) | -0.878*** | (0.041) |
| LLh | -62.481 | | -57.610 | |
| LRT | | | 0.000 | |

Note: The sample contains quarterly observations from 1975Q4 to 2015Q3. The superscript $x$ indicates regimes of price deviation. Standard errors are in the parentheses. *, **, and *** denote significance at 10%, 5% and 1%. LLh is the log likelihood value, and LRT the p-value of likelihood ratio test with restriction $\gamma^i = 0$.

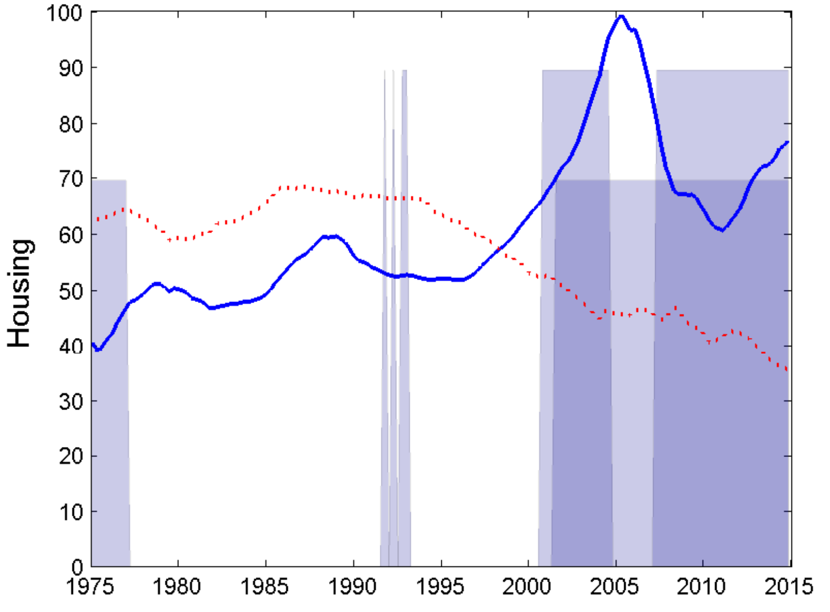


**FIG. 3** Regimes in the U.S. housing market. The solid and dashed lines denote the housing price and fundamental value. The taller areas denote the regime of small interest rate of the STAR-2 model and the shorter areas denote the regime of large price deviation.

regime of large price deviation covers periods before 1977 and after 2002 with a pronounced overlapping with the regime of low nominal interest rate.

As a short summary, based on the estimation results of STAR-2, speculative trading in the U.S. housing market is regime dependent with respect to both nominal interest rate and price deviation. When price deviation is small, fundamental traders push price away from the fundamental value, especially when nominal interest rate is low. On the contrary, when price deviation is large, fundamental traders drive price towards the fundamental value. For chartists, their trading does not depend on the price deviation. They always adopt the momentum trading which is enhanced when nominal interest rate is low. The regime dependent demand strength of traders, especially the contrary trading styles of fundamental traders, contrasts with the normal 'perceived' impression that fundamental traders always push price to the fundamental value. The wealth effect of stock market is always positive and is independent of the regimes of the nominal interest rate. In contrast, the wealth effect of disposable income is regime dependent. Disposable income has a small and negative effect when nominal interest rate is low and changes into a positive one when nominal interest rate is high. For the nominal interest rate which is a policy tool for the housing market, it is also regime dependent. When the nominal interest rate is low, increasing nominal interest rate has a positive effect to fuel the housing market. Only when the nominal interest rate is high, increasing nominal interest rate has the desired negative effect to cool down the housing market. This result is different from the theoretical conclusion of Himmelberg et al. (2005) that increasing interest rate always has a negative effect on house price. For the last variable inflation, it also has a regime dependent effect. When the nominal interest rate is low, an increase in general price level has a positive effect on house price. This positive effect disappears when nominal interest rate is high. The regime-dependent effect of inflation suggests a negative interaction effect arising from inflation when nominal interest rate switches from a low level to a high one. This negative interaction effect is consistent with the money illusion as discussed by Brunnermeier and Julliard (2008) that money illusion effect exhibits itself as a negative effect of inflation. Moreover, the money illusion is better measured in this paper since the fundamental value has been derived and controlled in our regression.

From our regression using the STAR-2 model in Table 3, the six variables are significant in explaining the price dynamics of the U.S. housing market. To further determine which factors are the key driving forces for the variance of the price change, we implement a relative importance analysis to partition explained variance among the multiple explanatory variables by using the method of relative weights

TABLE 4
Percentage of variance of price changes explained by the explanatory variables.

| Explanatory variables | $x_{t-1}$ | $\Delta P_{t-1}$ | $r_t^{st}$ | $\Delta y_t$ | $\Delta i_{t-1}$ | $\pi_{t-1}$ |
|---|---|---|---|---|---|---|
| Relative weights | 26.4% | 26.1% | 13.2% | 11.3% | 15.8% | 9.3% |

following Tonidandel and LeBreton (2011). As shown in Table 4, the variance of the price changes is mainly explained by speculative trading based on fundamental value (26.4%) and speculative chartist trading (26.1%), followed by nominal interest rate change (15.8%), wealth effect from stock market (13.2%), change of disposable income (11.3%), and inflation rate (9.3%). It can be seen that the speculative trading accounts more than 50% of the variance and has a dominant role for the housing market even though we take into account of the macro-finance factors. Therefore, it urges the attention for the speculative trading in designing policy for the housing market. Similar to Campbell et al. (2009), our finding is different from the result of Himmelberg et al. (2005) that interest rates are the key explanatory variables.

## 6. CONCLUSION

This paper investigates the price dynamics of U.S. housing market. In addition to the typical macro-finance factors, we also consider the speculative trading behaviors which can be decomposed into two different trading strategies. The two trading strategies rely on different information: fundamental value and non-fundamental ones such as the historical price movement. It is found that all the macro-finance and speculative variables have different behaviors in different regimes of nominal interest rate. In addition, the speculative trading also varies to different levels of price deviation to the fundamental value. It is worthy to highlight that there is a wealth effect from stock market to the housing market. Disposable income also has a positive effect when nominal interest rate is high. Depending on the level of nominal interest rate, increasing nominal interest rate has different outcomes. When nominal interest rate is low, instead of depressing the house price, increasing nominal interest rate boosts the market. Only when nominal interest rate is high, increasing nominal interest rate manages to cool down the market. Inflation rate also has regime dependent effect. When nominal interest rate is low, inflation increases house price. However, this boosting effect disappears in the regime of high nominal interest rate. As inflation often affects the expectation for future price movement, the regimes dependent behavior of inflation might suggest the regime dependent behaviors of expectation formation.

For speculative trading, fundamental traders rely on fundamental value for trading decision. They tend to push price away from fundamental value. This deviation enlargement trading is weakened when nominal interest rate becomes high. When price deviation reaches certain level and becomes large, fundamental traders trade in a converse way to drive the price towards the fundamental value. For the non-fundamental traders, chartists follow a momentum trading strategy to bet on the persistence of the recent trend of price movements. Their demand strength is weakened in the regime of high nominal interest rate. When price deviation is small, the trading styles of both fundamental traders and chartists push prices away from the fundamental value, generating the momentum phenomenon of house price reported by Case and Shiller (1989). When price deviation is large in a longer period, the convergence of price towards fundamental value contributed by fundamental trader corresponds to the phenomenon of mean reversion of Cutler et al. (1991). Our finding is similar to the result of Glaeser and Nathanson (2015) that momentum is mainly found in short horizon while mean reversion prevails in long horizon. The fact that fundamental traders drive price towards fundamental value when price deviation is large also suggests certain market efficiency or self-correction ability of the market. We conclude that the U.S. housing market has speculative trading as its largest driving force and shows certain market efficiency in the long run.


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