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Policy failure or success? Detecting market failure in China's housing market

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ABSTRACT

Due to a high vacancy rate of residential homes, housing prices remain sticky in most urban areas of China, which causes higher searching and bargaining costs. With an inefficient outcome, deadweight loss and market failure arises. To assess the Chinese government's housing policies in 2010, we develop a dynamic equilibrium model, in which we demonstrate how the sticky price results in market failure. We apply a multiple-factor panel data model to show that a high degree of market failure is associated with a high ratio of persistent components in the gap between price and equilibrium. As the persistent components will cause the market's instability, we can use the ratio between persistent and mean reverting components as an indicator to supervise the status of the housing market.

We investigate the new and second-hand markets in 19 major cities, including 4 municipalities and 15 vice-provincial cities. Through our multiple-factor model, we explore the situation for each city. The results indicate these policies did improve the housing market's efficiency. It is therefore useful for the Chinese government to extend these policies to other areas to include not only big cities, but entire provinces which can improve its economic system efficiency and fairness even when its economic growth is slowing down.

1. Introduction

Ever since China released the housing policy *State Council Document Number 10* on April 17, 2010, its housing market has experienced many changes. Various actions affecting the market include tightening mortgage rates, rising down payments for second homes, restricting house purchases, and rising property taxes.[1] China's government used these instruments to slow down the soaring housing prices and make houses affordable for the public. We are interested in the effects following the implementation of these policies, and whether the housing market became more efficient or just pulled back from the rising prices.

Regarding the new and second-hand housing markets, this article focuses on comparing the situations during pre- and post-policy shock periods. Following Parkin (2014), we define a market failure as a situation in which a market delivers an inefficient outcome. In order to evaluate a situation, we develop a dynamic equilibrium model, whereby we reveal the relationship between transaction cost and market failure. Because houses are unique and sellers usually post their selling price higher than the equilibrium to maximize their own profit (or increase their surplus), vacancies always exist, which provide buyers with more choices. If the number of vacancies is large, this indicates buyers might have more searching work to explore the suitable objectives. According to Commons (1931), transaction cost includes searching costs, bargaining costs, and policing and enforcement costs.

It is a well known fact that, China's economy features a high degree of income disparity. A report by the Peking University Institute of Social Science Survey showed that income inequality among Chinese citizens in 2014 had reached a severe condition, as the richest 1% of China's population possessed 1/3 of the country's wealth, while the poorest 25% of Chinese citizens owned only 1% of the country's wealth. Due to the perceived low risk of real estate, owning a house has always been one of the favored investments for wealthy Chinese. Compared to other countries, China's real estate tax is relatively low, with the tax for self-occupancy at 0% and non-self-occupancy between 0.4% and 0.6%, which are far below other countries, like Singapore, at 4% (self-occupied) and 10% (not self-occupied). This is one of several factors supporting China's high housing prices. Some places even have so-called "luxury residence"

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[1] The government tested new property taxes in Shanghai and Chongqing. The property tax rate in Shanghai is set between 0.4% and 0.6% and in Chongqing between 0.5% and 1.2%.

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units with astonishingly high prices that are unaffordable for average income residents, while vacant units are still widely scattered over these communities. More seriously, some areas gained media attention for having ghost cities due to a large inventory of vacant houses. This is why the Chinese government implemented the housing policies in 2010. Real estate is an asset form with limited liquidity and is capital intensive when compared to other investments. Therefore, the housing market plays a crucial role in an economic system. If it cannot allocate resources efficiently, then this not only influences capital flow and resource allocation, but also affects a country's economic growth.

A speculator invests money in the housing market in order to gain a return in the future. If the government raises the mortgage interest rate and tax rate, then this indicates a rising opportunity cost to own a house, and as such demand will decrease. At the same time, it also increases the holding cost for a vacancy, which will push the rigid price toward equilibrium quickly and force the sellers to cut their prices in order to shorten their holding period, which will increase the quantity demanded and decrease the quantity supplied. This study investigates the effects of China's housing policies in 2010. As new and second-hand housing markets have different characteristics, we detect market failures in the two and evaluate their effects.

There is a lot of literature discussing the behavior of housing prices. Kenny (1999) applied a co-integration analysis to identify the variables of demand and supply sides of the Irish housing market, in which income, mortgage interest rate, and housing stock are used to evaluate short- and long-run relationships. Zhang et al. (2012) used a nonlinear time series model with key factors including mortgage rate, producer price, money supply and real exchange rate to interpret dynamics of housing prices. Zhang et al. (2013) argued that the high housing prices are partly caused by some real factors, and provided a calibrated model to estimate the effects of policies that control land use on housing prices in China. Guan (2013), Kang and Liu (2014), and Feng and Wu (2015) addressed the problem of soaring housing prices in China and discussed what caused houses to become unaffordable. Zeng et al. (2013) analyzed the effect of household wealth on housing sales and probed their long-run and short-run dynamic relationships, which show that housing wealth, income, and mortgage rates affect housing sales in the long-run. Selcuk (2013) developed an equilibrium search model of the housing market, in which the sale time expresses the sellers' distress when the houses are unable to sell. Wang and Zhang (2014) evaluated the importance of fundamental changes in explaining the rising housing prices in urban China in the 2000s. Shih et al. (2014) used a unit root test to detect when housing price bubbles were rising, in which prices could have a potential contagious effect among the provinces. Wen and He (2015) used a dynamic stochastic general equilibrium model to investigate the key driving force of housing price fluctuations. Zhang (2015) demonstrated a significant correlation exists between income inequality and housing-price-to-income ratio, and showed the importance to keep housing price reasonable. Feng and Wu (2015) as well as Cai and Lu (2015) investigated rapid housing price growth and a high price-to-income ratio in major Chinese cities and discussed whether there is an asset bubble in China's residential housing market. They focused on affordability when developing a housing policy and proposed a broader housing appropriateness concept.

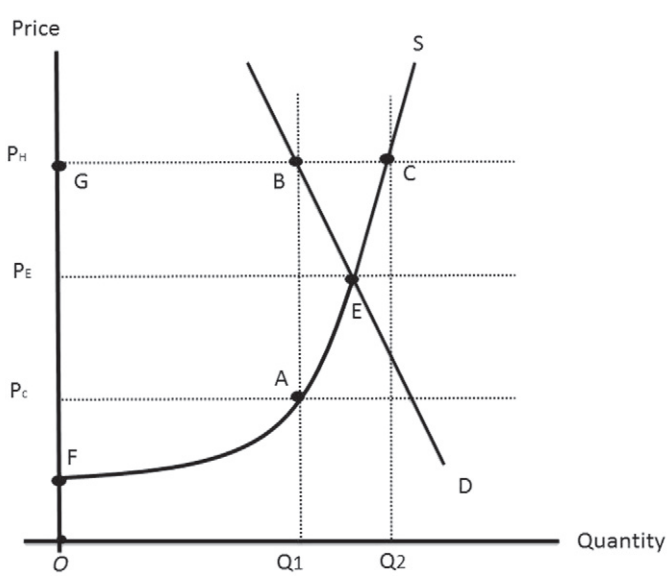


Fig. 1. Because a house is unique and the seller maximizes his or her profit, the price is usually set publicly above the equilibrium at the beginning. Thus, vacancies always exist. Suggesting the beginning price is set at P_H, as the quantity supplied is greater than the quantity demanded (between B and C), the vacant houses provide the buyers more choices. This will cause a searching and bargaining cost. In this case, if the quantity supplied is fixed at Q_1, then the marginal benefit (B point) is far higher than marginal cost (A point), and there exists a lot of bargain space. Eventually, the transaction price might fall toward equilibrium price P_E, but the searching and bargaining cost already has arisen. If this market is at a low degree of transparency, then the gap between the price and equilibrium will become persistent.

There is also an alternative stream of literature focusing on market failure. For example Gallin (2006) initiated panel data tests to detect the co-integrated relationship, which includes several variables, such as income per capita, the construction wage, user cost, population, and stock market. The author showed that even researchers who used powerful tests still cannot find the co-integration relationship, suggesting that the error-correction specification for house prices and income commonly found in the literature may be inappropriate. Tsai (2013) demonstrated the defensive characteristics of housing prices known as downward price rigidity by using the loss aversion behavior of traders to assess the viability of housing price rigidity.

He (2013) and Barros et al. (2014) demonstrated that housing supply and demand have a time lag and noted that it is reasonable to have vacancy areas. He (2013) used Chengdu as an example. He illustrated the market failure and suggested that the local government should intervene in the housing market to ensure the city's development. Barros et al. (2014) used Beijing as an example and provided a framework by using the number of vacant houses to explain the delay of house sales. Cao and Keivani (2014) provided a review of China's urban housing outcomes, revealing housing price inflation and a shortage of affordable housing in the fast expanding housing market. They advocated for more effective and direct public intervention for enhancing social housing provisions and tightening market regulations for lower income groups. Liu and Wong (2015) investigated the causes of misallocation of economic housing in Beijing, and addressed the importance of balancing the growth-led policy with social equity and redistribution of public resources. Zhou (2016) used Shanghai as an example, demonstrating the overreaction to policy changes in the housing market, in which the long-term investors overreact less than consumers.

Different from previous studies, this article emphasizes the degree of market failure. We suggest that market failure prevalently exists, and the gap between housing prices and the market equilibrium may be comprised of different components, including persistence and mean reversion. If the component shows a mean reversion characteristic, then this indicates the price will adjust itself quickly toward the equilibrium. This is different from a component that possesses a persistent characteristic, whose price will not move toward equilibrium. We compare the pre- and post-housing policy periods and measure the proportions of persistence, which represents the degree of market failure.

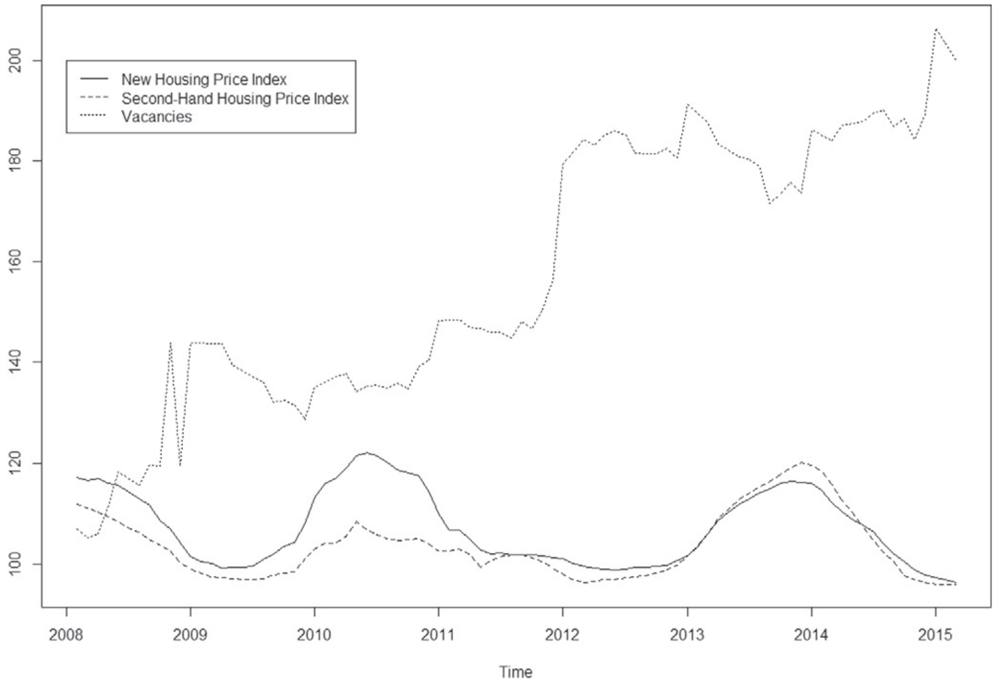


Fig. 2. Beijing's vacancies and housing price indices. The vacancies here denote the volume of the current vacant area of commercialized buildings in Beijing, with the data coming from the China Index Academy in units of 100,000 m^2.

The remainder of this paper is arranged as follows. In Section 2 we develop a dynamic equilibrium model and discusses the capital flows between the housing market and other assets. Because transactions in China's housing market are mostly traded through housing agents, potential buyers spend a lot of time researching information, bargaining, negotiating, etc. When the market has a lot of vacancies with a low degree of transparency, the transaction cost will be large. We suggest the size of the transaction cost will influence the behavior of housing prices. In Section 3 we develop a likelihood function to estimate the factors concealed in the housing market, and determine if these factors have different adjustment speeds. In Section 4 we apply our model to China's new and second-hand housing markets, in which a portion with non-stationary factors are measured to show the degree of market failure. In the estimation, we apply the bootstrap method to recognize whether each factor is stationary or not. We further plot the relationship between factors' root-mean-square error (RMSE) and adjustment speeds, showing that heterogeneity and market failures commonly exist in cities. In Section 5 we give concluding remarks, summarizing this paper's contributions.

Table 1
We measure the adjustment speed based on different levels of transaction cost θ. Boundary k is affected by θ, and we simply assumes $k = 1 - \theta$. We calculate the adjustment speed by using the ADF test, and the adjustment speed equals the absolute value of the ADF coefficient, where * denotes rejection of the null hypothesis at the 5% significance level.

Parameter[a]			ADF test	
γ	θ	k	Coefficient	t value
−0.05	0.10	0.90	−0.4480*	−4.9701[b]
−0.05	0.20	0.80	−0.3749*	−4.0638
−0.05	0.30	0.70	−0.2780	−3.4404
−0.05	0.40	0.60	−0.1367	−2.7508
−0.10	0.10	0.90	−0.3632*	−4.2515
−0.10	0.20	0.80	−0.3144*	−4.2266
−0.10	0.30	0.70	−0.4526	−3.2508
−0.10	0.40	0.60	−0.1892	−1.6489

[a] We simply set the growth rates of housing and other assets at $\nu = \mu = 0.8$, and depreciation and discounting rate $\alpha = \tau = 0.03$. Coefficient β is equal to the marginal product of capital multiplied by propensity of consumption, and let $\beta = 0.03$. The error term is generated by normal distribution.

[b] Critical value is for the unit root test of −3.45, under the significance level of 5%.

2. Transaction cost, market failure, and instability

The real estate market is not as organized or efficient as markets for other more liquid investment instruments. Every unit is unique, which reveals a large challenge to an investor seeking investment opportunities and evaluating prices. In China, if one wants to buy a house, it is usually done through a housing agent for bargaining and negotiating. Due to information asymmetries, house prices within the same community could vary widely. As a highly intensive capital investment, buying a house usually entails a lot of preparation work, which depends highly on the availability of knowledge. This provides opportunities for investors to obtain properties at bargain prices.

As each house is unique, the seller usually sets the public price above the equilibrium to maximize his or her own profit, and thus vacancies always exist.[2] Referring to Fig. 1, we show their relationship. Assuming the seller sets the price at P_H in the beginning, there are Q_2 quantity supplied, which provide buyers more choices than quantity demanded Q_1. This is especially true when the vacancy amount is huge and the market has a low degree of transparency, which will cost the buyers a lot of time to search and bargain. The final sale price might fall, but this will cost time on searching and bargaining, which increases the transaction cost. We use Beijing as an example (see Fig. 2). The vacancies here denote the volume of the current vacant area of commercialized buildings in Beijing, with the data coming from the China Index Academy in units of 100,000 m^2. According to a nationwide survey by the Survey and Research Center

[2] In reality, a seller could set the house price below equilibrium when a financial crisis happens, but if the price is below equilibrium, then according to the law of demand and supply (short-side rule), there exists excess demand and houses will be sold quickly and no longer remain on the market. Thus, these houses that remain on the market (on sale or flowing in the housing market) have prices that are mostly higher than the equilibrium.

for China Household Finance (researchers from China's Southwestern University of Finance and Economics), the vacancy rate of sold residential homes in urban areas hit 22.4% in 2013, up from 20.6% in 2011, which is far above the level of developed countries (e.g., the homeowner vacancy rate in the United States was only about 3% during the peak of the U.S. housing bubble around 2006). Fig. 2 shows the number of vacancies quickly climbed, but prices did not fall down, showing their stickiness.

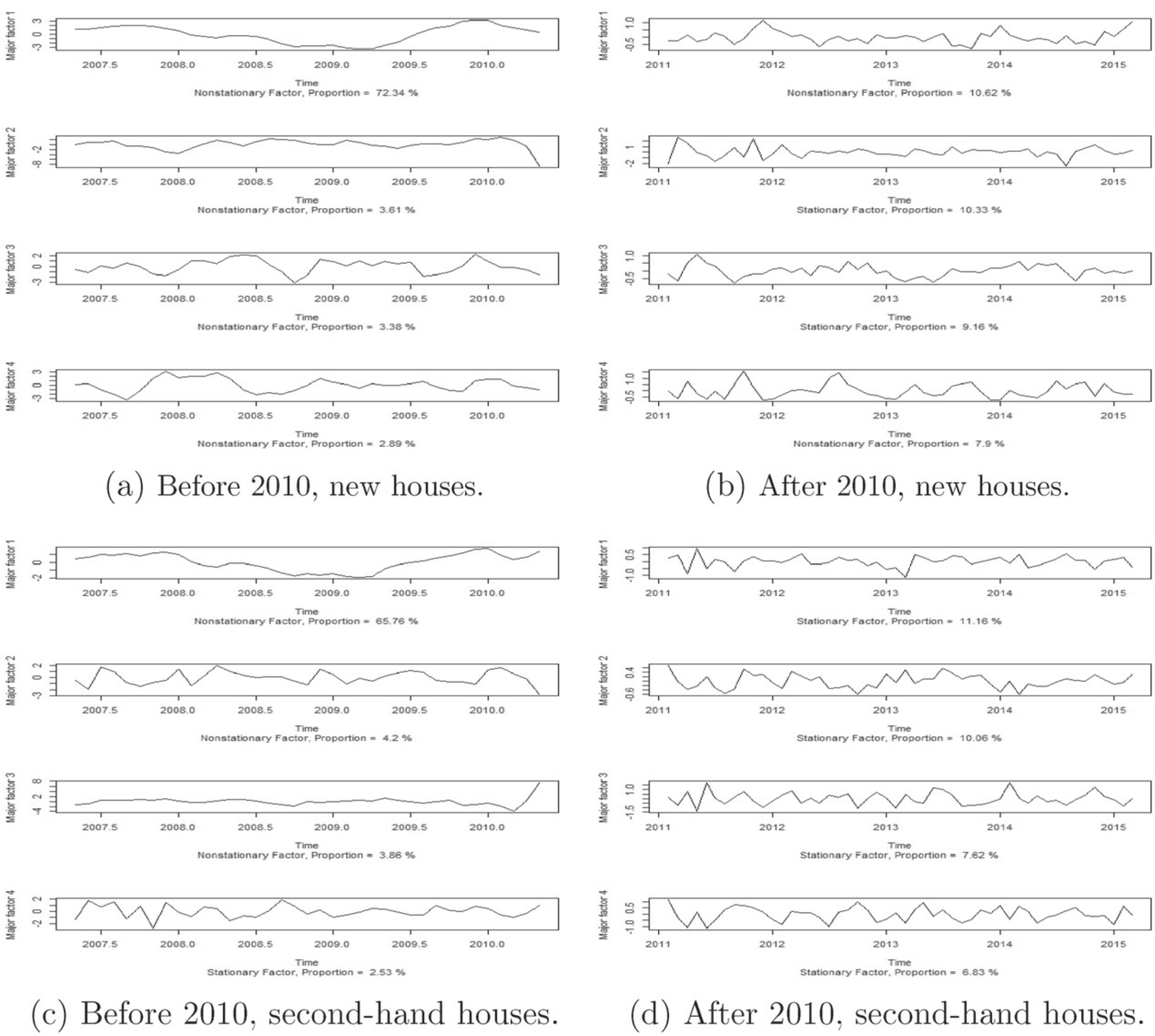
In the following context, we provide a model to exhibit how transaction cost influences price behavior. We first assume a value function for an investor.

$$V(H_t,\ W_t) = \max_{W,\ H}\ E_t \int_t^{\infty} e^{-\tau(u-t)} U(c_t,\ H_t)\, du,$$

where H_t denotes the capital in terms of dollars invested in the housing market at time t, W_t denotes the capital invested in other assets, and c_t is consumption. The definitions of variables can be seen in Appendix A. These two types of capital have the following processes.

$$dH_t = (\nu - \alpha) H_t dt + (1-\theta) dI_t - dD_t,$$
$$dW_t = (W_t \mu - c_t)\, dt - dI_t + (1-\theta) dD_t + \sigma_W W_t dz_t,$$

where I_t denotes the cumulated funds transferred from other assets into the housing market, while D_t denotes the funds flowing in the opposite direction. Parameter α is the depreciation rate, and ν and μ are the appreciation (growth) rates of capital in housing and other assets, respectively. Transaction cost is represented as θ, which denotes how much capital is lost when entering and leaving the market. Disturbance dz_t denotes uncertainty about other assets and σ_W is the standard deviation. If the rate of H_t/W_t falls outside the range of $(k, 1/k)$ where $0 < k < 1$, then capital begins flowing. If k decreases, then the range becomes wider, indicating more difficulty in trading. We assume here that k is affected by transaction cost θ. If the transaction cost increases, then the boundary becomes wider; that is, $k_\theta < 0$.



(a) Before 2010, new houses. (b) After 2010, new houses. (c) Before 2010, second-hand houses. (d) After 2010, second-hand houses.

Fig. 3. The first four factors with the largest sum of squares in different markets, including new and second-hand housing markets separated by 2010.

Here we notice that one transaction could contain two sides; one is for the buyer who moves capital into the housing market, and the other is for the seller who moves capital away from the housing market. Some exceptions have only one side. For example, when a house is converted into a warehouse and is no longer for sale, this indicates capital leaving the housing market. Alternatively if a person buys a new house, then capital flows into the housing market. Through the Bellman equation, we have:

$$\tau V = U\left(c_t,\ H_t\right) + (\nu - \alpha)H_t V_H + \left(W_t\mu - c_t\right)V_W + \frac{1}{2}\sigma_W^2 W_t^2 V_{WW}. \quad (1)$$

At the boundary, we have:

$$\text{Entering: } V\left(H_t,\ W_t\right) = V\left(H_t + (1-\theta)dI_t,\ W_t - dI_t\right) \text{ and}$$
$$\text{Leaving: } V\left(H_t,\ W_t\right) = V\left(H_t - dD_t,\ W_t + (1-\theta)dD_t\right),$$

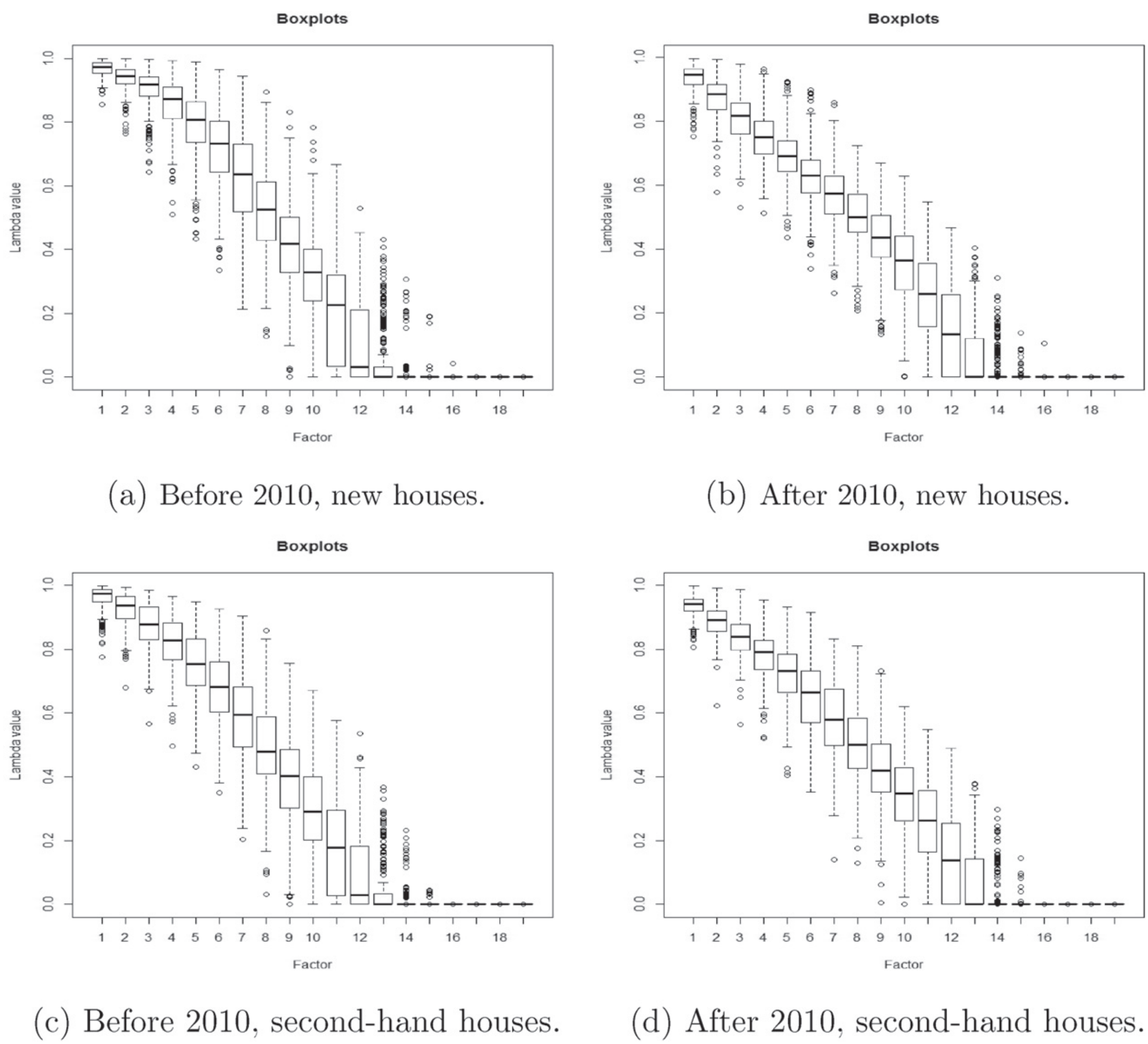
which can be extended by the Taylor expansion. We then have the first-order relationships for entering and leaving the housing market:

$$\text{Entering: } (1-\theta)V_H - V_W = 0 \text{ and}$$
$$\text{Leaving: } V_H - (1-\theta)V_W = 0,$$

where V_H and V_W represent the marginal values of housing and other assets per dollar, respectively.

We first assume that there is no transaction cost ($\theta = 0$). According to the principle of diminishing marginal value, if we excessively invest capital in the housing market, then $V_H < V_W$. In the short run, because capital is fixed, house prices will fall, and marginal values per dollar for different assets move convergently; that is, $V_H = V_W$. In the long run, investors get the most value possible from their limited resources. When house prices are low, capital will move away from the housing market to other assets. With an efficient adjustment (no transaction cost), this will cause prices to adjust quickly and to fluctuate stationarily (mean reversion) around the equilibrium. However, if the market is not transparent and buyers continue searching and bargaining, there will be a gap between the observed price and equilibrium that becomes persistent, causing the transaction cost to rise.

Transaction cost in the housing market always exists; that is, $\theta \in (0, 1)$. If θ increases indicating the transaction cost increases, then k decreases, which will make the flow of capital more difficult. Thus, the discrepancy between the observed price and equilibrium is more persistent in the long run. In other words, if the transaction cost is high, then housing prices have a high probability to deviate from the equilibrium. The gap between housing prices and equilibrium then



(a) Before 2010, new houses.

(b) After 2010, new houses.

(c) Before 2010, second-hand houses.

(d) After 2010, second-hand houses.

Fig. 4. Applying the block bootstrap method with 300 times of resample replacement. The boxplots show the quartiles for each factor. With the confidence interval, ($Q_1 - 1.5\Delta Q$, $Q_3 + 1.5\Delta Q$) where $\Delta Q = Q_3 - Q_1$, we have 10 stationary and 9 non-stationary factors for each market.

likely exhibits non-stationarity. One extreme case is if $k = 0$ (when $\theta = 1$), then no capital is flowing. Housing prices are completely disconnected from equilibrium.

In general cases, different types of θ (or k) exist. If the value of θ is small (k is large), then the series is more likely moving toward mean reversion. Otherwise, with a large θ (small k), the series tends to be persistent. We use the price adjustment speed here to evaluate the degree of market failure. If a market is more transparent and efficient, then the adjustment price speed is faster, which is reflected in prices showing a mean reversion process with a high speed adjustment coefficient around equilibrium. Otherwise, an inefficient market exhibits a persistent characteristic. Considering the heterogeneity of transaction cost, this article develops a multiple factor model that contains different adjustment speed factors. To illustrate the relationship between the speed of mean reversion and θ, we apply a constant relative risk aversion utility function. We present the utility function as $U(c_t,\ H_t) = \frac{c_t^\gamma}{\gamma} + \frac{H_t^\gamma}{\gamma}$, where $c_t = \beta W_t$, and β is the rate of consumption in capital stock and is equal to marginal production of capital times consumption propensity. The value function can then be obtained as the following (see the proof in Appendix B):

$$V(H_t,\ W_t;\ \alpha,\ \beta,\ \tau,\ \gamma) = \left[\frac{1}{\tau-(\nu-\alpha)\gamma}\right]\frac{H_t^\gamma}{\gamma} + \left[\frac{1}{\tau-\frac{1}{2}\sigma^2\gamma^2-\left(\mu-\beta-\frac{1}{2}\sigma^2\right)\gamma}\right]\frac{(\beta W_t)^\gamma}{\gamma} + A_1 H_t^{\gamma-s_1} W^{s_1} + A_2 H_t^{\gamma-s_2} W^{s_2}.$$

Here, s_1 and s_2 are the roots of $\frac{1}{2}\sigma^2 s^2 + \left(\alpha-\nu+\mu-\beta-\frac{1}{2}\sigma^2\right)s + (\nu-\alpha)\gamma-\tau = 0$.

Considering different levels of θ (or k), we can detect the mean reversion speed by using the Augmented Dickey–Fuller (ADF) test. Without losing generality, we set the growth rate (according to China's GDP growth rate), depreciation, and discount rate (China real interest rate) at 0.08, 0.03, and 0.03 respectively. Table 1 shows the results of the simulations with different values for θ, where $k = 1-\theta$. If θ increases from 0.1 to 0.4, then the adjustment speed (absolute value of ADF coefficient) decreases from 0.4480 to 0.1367, when $\gamma = -0.05$.[3] This supports our hypothesis that when the transaction cost increases, the gap becomes persistent and the market is more inefficient.

Table 2
This table shows the persistent and mean reversion proportions[a] from the common components concealed in the gap between the price and equilibrium for the new housing market between April 2007 and April 2010, before the implication of the housing policies. The numbers of stationary and non-stationary factors are 9 and 10, respectively.

City name	Coefficients $\hat{\rho}-1$[b]	Coefficients $\hat{\sigma_\rho}$	ADF value $\frac{\hat{\rho}-1}{\hat{\sigma_\rho}}$	Portion of sum of squares	Type of series
Beijing	−0.1093	0.0773	−1.4132	0.7695	$\hat{g}^n$
Beijing	−1.2876**[c]	0.2643	−4.8712	0.2305	$\hat{g}^s$
Tianjin	−0.0809	0.0663	−1.2197	0.8358	$\hat{g}^n$
Tianjin	−1.3173**	0.232	−5.6773	0.1642	$\hat{g}^s$
Shanghai	−0.1484	0.0786	−1.8890	0.7397	$\hat{g}^n$
Shanghai	−0.9738**	0.2171	−4.4848	0.2603	$\hat{g}^s$
Chongqing	−0.1624	0.0936	−1.7357	0.8762	$\hat{g}^n$
Chongqing	−1.1028**	0.2347	−4.6978	0.1238	$\hat{g}^s$
Guangzhou	−0.0818	0.0506	−1.6179	0.9278	$\hat{g}^n$
Guangzhou	−1.2515**	0.1817	−6.8886	0.0722	$\hat{g}^s$
Wuhan	−0.1746	0.1086	−1.6073	0.8132	$\hat{g}^n$
Wuhan	−1.1643**	0.2582	−4.5094	0.1868	$\hat{g}^s$
Chengdu	−0.0809	0.0599	−1.3513	0.888	$\hat{g}^n$
Chengdu	−1.4711**	0.258	−5.7019	0.112	$\hat{g}^s$
Nanjing	−0.101	0.0677	−1.4917	0.8747	$\hat{g}^n$
Nanjing	−1.1764**	0.2569	−4.5789	0.1253	$\hat{g}^s$
Shenyang	−0.2791	0.1218	−2.2923	0.7275	$\hat{g}^n$
Shenyang	−1.1833**	0.2347	−5.0417	0.2725	$\hat{g}^s$
Xian	−0.2629	0.136	−1.9328	0.756	$\hat{g}^n$
Xian	−1.2885**	0.2285	−5.6391	0.244	$\hat{g}^s$
Shenzhen	−0.0829	0.0579	−1.4322	0.8644	$\hat{g}^n$
Shenzhen	−1.077**	0.1981	−5.4358	0.1356	$\hat{g}^s$
Harbin	−0.2749	0.1173	−2.3442	0.6763	$\hat{g}^n$
Harbin	−1.0665**	0.2278	−4.6811	0.3237	$\hat{g}^s$
Changchun	−0.2861	0.1263	−2.2658	0.7672	$\hat{g}^n$
Changchun	−1.4254**	0.2714	−5.2517	0.2328	$\hat{g}^s$
Dalian	−0.1216	0.1191	−1.0207	0.8127	$\hat{g}^n$
Dalian	−1.4398**	0.2476	−5.8153	0.1873	$\hat{g}^s$
Jinan	−0.1601	0.1005	−1.5928	0.2195	$\hat{g}^n$
Jinan	−1.4655**	0.2075	−7.0621	0.7805	$\hat{g}^s$
Qingdao	−0.1212	0.1065	−1.1377	0.7611	$\hat{g}^n$
Qingdao	−1.2853**	0.2617	−4.9123	0.2389	$\hat{g}^s$
Hangzhou	−0.1896	0.098	−1.9353	0.803	$\hat{g}^n$
Hangzhou	−1.113**	0.2514	−4.428	0.197	$\hat{g}^s$
Ningbo	−0.2109	0.1036	−2.0363	0.8152	$\hat{g}^n$
Ningbo	−1.1968**	0.2704	−4.4259	0.1848	$\hat{g}^s$
Xiamen	−0.0782	0.0523	−1.4941	0.9367	$\hat{g}^n$
Xiamen	−1.2351**	0.2495	−4.9500	0.0633	$\hat{g}^s$

where * and ** denote rejections of the null hypotheses at the 5% and 10% significance levels.

[a] The pricing equation is $\log P_t = \hat{\beta}_0 + \hat{\beta}_1 \log y_t + \hat{\beta}_2 p_{f,t} + \hat{\beta}_3 i_t + \hat{\beta}_4 t + \hat{g}_t$, where $\hat{g}_t = \hat{g}_t^s + \hat{g}_t^n$, and $\hat{g}_t^s$ and $\hat{g}_t^n$ represent the stationary and non-stationary parts, respectively. The proportions are measured by the sum of squares in total, and we use the ADF test to verify the property of the decomposed series, where the best BIC is used for the lag length.

[b] The ADF model is $\Delta g_t = \alpha + (\rho-1)g_{t-1} + \delta_1 \Delta g_{t-1} + \ldots + \delta_p \Delta g_{t-p} + a_t$.

[c] The critical values at the significance level of 5% and 10% are −3.45 and −3.15, respectively.

3. Detecting persistent and mean reversion factors

This section investigates how to recognize the stationary and non-stationary components in the housing market and constructs the objective function by the mean squared errors for the panel data. Following Gallin (2006), we establish a reduced-form housing price as follows:

$$P_t = h(y_t,\ r_t,\ p_{f,\,t}) + g_t, \tag{2}$$

where P_t, y_t, r_t, and $p_{f,t}$ represent the house price, income, mortgage interest rate, and production factor price,[4] respectively. Note that y_t and r_t show the effects from the demand side, indicating income effect and opportunity cost for buying a house; and $p_{f,\,t}$ comes from the supply side, implying the production cost. The error term g_t expresses the gap between the observed price and the expected value.

According to previous discussions, if the market trades freely and efficiently, then g_t will tend to show stationary tendencies and the price will fluctuate around the equilibrium price $h(y_t, r_t, p_{f,\,t})$. Otherwise, g_t demonstrates a non-stationary property and market failure. Associated with N cities, we set a one-period lagged model:

$$\Delta \boldsymbol{g}_t = \boldsymbol{\zeta}_0 + \boldsymbol{\zeta}_1 \boldsymbol{g}_{t-1} + \boldsymbol{u}_t, \text{ for } t = 1, \ldots, T, \tag{3}$$

where $\Delta \boldsymbol{g}_t' = [\Delta g_{1,\,t},\ \Delta g_{2,\,t}, \ldots, \Delta g_{N,\,t}]$, $\boldsymbol{g}_{t-1}' = [g_{1,\,t-1},\ g_{2,\,t-1}, \ldots, g_{N,\,t-1}]$, and $u_t' = [u_{1,\,t},\ u_{2,\,t}, \ldots,\ u_{N,\,t}]$. Here, $\boldsymbol{\zeta}_0$[5] is an $N \times 1$ intercept vector, $\boldsymbol{\zeta}_1$ is an $N \times N$ matrix, N is the cross section dimension, and T

[3] Similar results are revealed when $\gamma = -0.10$.

[4] Gallin (2006) uses income per capita, the construction wage, user cost, population, and stock market as explanatory variables. In that article, surprisingly, stock market and population have negative effect. Thus, in this article we use income per capita, mortgage interest rate, and construction wage as the explanatory variables, where we use producer price index as a proxy variable for construction wage.

[5] If we use demeaned and de-trended time series, then we can neglect the intercept terms.

is the time dimension. The observation $g_{k,t}$ represents the gap of the kth city at time t, and $\Delta g_{k,t}$ is its first difference, for $k = 1, \ldots, N$.

We assume the matrices $\Omega_{11} = \frac{1}{T}\sum_{t=1}^{T}\Delta\tilde{\boldsymbol{g}}_t\Delta\tilde{\boldsymbol{g}}_t'$, $\Omega_{22} = \frac{1}{T}\sum_{t=1}^{T}\tilde{\boldsymbol{g}}_{t-1}\tilde{\boldsymbol{g}}_{t-1}'$, and $\Omega_{12} = \frac{1}{T}\sum_{t=1}^{T}\Delta\tilde{\boldsymbol{g}}_t\tilde{\boldsymbol{g}}_{t-1}'$, where $\tilde{\boldsymbol{g}}_{t-1}$ and $\Delta\tilde{\boldsymbol{g}}_t$ are the deviations of $\boldsymbol{g}_{t-1}$ and $\Delta\boldsymbol{g}_t$, respectively. The coefficient matrix of $\Delta\boldsymbol{g}_t$ on regressor $\boldsymbol{g}_{t-1}$ is $\Omega_{12}\Omega_{22}^{-1}$. If $\boldsymbol{g}_t$ is non-stationary, then the stochastic order of the magnitude of Ω_{22} is $O_p(T)$, and the coefficients will approach zero as $T \to \infty$.

According to Johansen (1991), we can obtain the stationary and non-stationary components according to the cointegrated vectors and non-cointegrated vectors. The eigenvalues and eigenvectors associated with the canonical correlation matrices have the following relationships:

$$\Omega_{22}^{-1}\Omega_{21}\Omega_{11}^{-1}\Omega_{12}b_j = \lambda_j b_j \text{ and } \Omega_{11}^{-1}\Omega_{12}\Omega_{22}^{-1}\Omega_{21}k_j = \lambda_j k_j, \tag{4}$$

where eigenvalues $\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_N$ and their corresponding eigenvectors are $(b_1, b_2, \ldots, b_N)$ and $(k_1, k_2, \ldots, k_N)$. We may express the above equation in an alternative form:

$$b_j'\Omega_{21}\Omega_{11}^{-1}\Omega_{12}b_j = \lambda_j b_j'\Omega_{22}b_j.$$

The order of the left-hand side is $O_p(1)$, while the order of the right-hand side depends on the combination vector b_j. If $b_j'\tilde{\boldsymbol{g}}_{t-1}$ is stationary, then the order of the right-hand side is $O_p(1)$ and $0 < \lambda_j < 1$. Otherwise, if the value of $b_j'\tilde{\boldsymbol{g}}_{t-1}$ is non-stationary, its order becomes $O_p(T)$, and λ_j will approach to zero. Through λ_j, we can recognize whether each factor is stationary or non-stationary.

In order to normalize the common factors, we use normalized eigenvectors by $\tilde{b}_j'\Omega_{22}\tilde{b}_j = 1$ and $\tilde{k}_j'\Omega_{11}\tilde{k}_j = 1$, where $\tilde{b}_j = b_j \div \sqrt{b_j'\Omega_{22}b_j}$, $\tilde{k}_j = k_j \div \sqrt{k_j'\Omega_{11}k_j}$, $\tilde{B} = \left[\tilde{b}_1, \tilde{b}_2, \ldots, \tilde{b}_N\right]$, and $\tilde{K} = \left[\tilde{k}_1, \tilde{k}_2, \ldots, \tilde{k}_N\right]$. As $\tilde{B}'\Omega_{22}\tilde{B} = I$, we regard $\Omega_{22}\tilde{B}$ as the inverse matrix of $\tilde{B}'$, and thus we can rebuild the observations by the factors:

$$\tilde{\boldsymbol{g}}_t = \Omega_{22}\tilde{B}\boldsymbol{f}_t. \tag{5}$$

When $\tilde{B}'\Omega_{22}\tilde{B} = I$, the inverse matrix of $\tilde{B}'$ equals $\Omega_{22}\tilde{B}$. Regardless of whether this is pre- or post-multiplied by its inverse, the product will have the same identity. Thus, we have $\Omega_{22}\tilde{B}\tilde{B}' = I$. Replacing Ω_{22}^{-1} by $\tilde{B}\tilde{B}'$, the coefficients of $\Delta\boldsymbol{g}_t$ on regressor $\boldsymbol{g}_{t-1}$ in Eq. (3) can be obtained:

$$\boldsymbol{\zeta}_1 = \Omega_{12}\tilde{B}\tilde{B}'. \tag{6}$$

Table 3
This table shows the persistent and mean reversion proportions[a] from the common components concealed in the gap between the price and equilibrium for the new housing market between January 2011 and February 2015, after the implication of the housing policies. The numbers of stationary and non-stationary factors are 9 and 10, respectively.

City name	Coefficients		ADF value	Portion of	Type of	Efficiency
	$\hat{\rho}-1$[b]	$\hat{\sigma}_\rho$	$\frac{\hat{\rho}-1}{\hat{\sigma}_\rho}$	sum of squares	series	
Beijing	−0.0445	0.05	−0.8883	0.619	$\hat{g}^n$	
Beijing	−0.5061**[c]	0.1309	−3.8657	0.381	$\hat{g}^s$	↑[d]
Tianjin	−0.0413	0.055	−0.7499	0.6696	$\hat{g}^n$	
Tianjin	−0.5262**	0.1364	−3.8574	0.3304	$\hat{g}^s$	↑
Shanghai	−0.0561	0.0543	−1.0335	0.5694	$\hat{g}^n$	
Shanghai	−0.5875**	0.1483	−3.9612	0.4306	$\hat{g}^s$	↑
Chongqing	−0.0301	0.0525	−0.5745	0.7368	$\hat{g}^n$	
Chongqing	−0.6782**	0.1569	−4.323	0.2632	$\hat{g}^s$	↑
Guangzhou	−0.059	0.0498	−1.1841	0.624	$\hat{g}^n$	
Guangzhou	−0.7361**	0.1737	−4.2387	0.376	$\hat{g}^s$	↑
Wuhan	−0.0497	0.0533	−0.9335	0.6064	$\hat{g}^n$	
Wuhan	−0.5284**	0.1423	−3.7126	0.3936	$\hat{g}^s$	↑
Chengdu	−0.0348	0.0551	−0.6325	0.5894	$\hat{g}^n$	
Chengdu	−0.5868**	0.1531	−3.8317	0.4106	$\hat{g}^s$	↑
Nanjing	−0.044	0.0505	−0.8719	0.6297	$\hat{g}^n$	
Nanjing	−0.5908**	0.1383	−4.273	0.3703	$\hat{g}^s$	↑
Shenyang	−0.0435	0.0553	−0.7859	0.6027	$\hat{g}^n$	
Shenyang	−0.5395**	0.1456	−3.7062	0.3973	$\hat{g}^s$	↑
Xian	−0.0434	0.0573	−0.7571	0.5712	$\hat{g}^n$	
Xian	−0.5008**	0.1365	−3.6692	0.4288	$\hat{g}^s$	↑
Shenzhen	−0.0659	0.0519	−1.2707	0.6307	$\hat{g}^n$	
Shenzhen	−0.553**	0.1419	−3.8979	0.3693	$\hat{g}^s$	↑
Harbin	−0.0318	0.0601	−0.5289	0.6319	$\hat{g}^n$	
Harbin	−0.5056*	0.1525	−3.315	0.3681	$\hat{g}^s$	↑
Changchun	−0.0522	0.0663	−0.7879	0.5982	$\hat{g}^n$	
Changchun	−0.4799**	0.1353	−3.5463	0.4018	$\hat{g}^s$	↑
Dalian	−0.0311	0.0536	−0.58	0.5957	$\hat{g}^n$	
Dalian	−0.5769**	0.1491	−3.8695	0.4043	$\hat{g}^s$	↑
Jinan	−0.0388	0.0546	−0.7111	0.6295	$\hat{g}^n$	
Jinan	−0.4801**	0.1351	−3.5546	0.3705	$\hat{g}^s$	↓
Qingdao	−0.0487	0.0558	−0.8725	0.5095	$\hat{g}^n$	
Qingdao	−0.5179**	0.1385	−3.7392	0.4905	$\hat{g}^s$	↑
Hangzhou	−0.0832	0.0571	−1.4567	0.5517	$\hat{g}^n$	
Hangzhou	−0.4911*	0.1226	−4.0072	0.4483	$\hat{g}^s$	↑
Ningbo	−0.0807	0.0674	−1.1972	0.5053	$\hat{g}^n$	
Ningbo	−0.4243**	0.1182	−3.5894	0.4947	$\hat{g}^s$	↑
Xiamen	−0.0546	0.0553	−0.9882	0.5767	$\hat{g}^n$	
Xiamen	−0.4978**	0.1308	−3.8072	0.4233	$\hat{g}^s$	↑

where * and ** denote rejections of the null hypotheses at the 5% and 10% significance levels.
[a] The pricing equation is $\log P_t = \hat{\beta}_0 + \hat{\beta}_1 \log y_t + \hat{\beta}_2 p_{f,t} + \hat{\beta}_3 i_t + \hat{\beta}_4 t + \hat{g}_t$, where $\hat{g}_t = \hat{g}_t^s + \hat{g}_t^n$, and $\hat{g}_t^s$ and $\hat{g}_t^n$ represent the stationary and non-stationary parts, respectively. The proportions are measured by the sum of squares in total, and we use the ADF test to verify the property of the decomposed series, where the best BIC is used for the lag length.
[b] The ADF model is $\Delta g_t = \alpha + (\rho-1)g_{t-1} + \delta_1\Delta g_{t-1} + \ldots + \delta_p\Delta g_{t-p} + a_t$.
[c] The critical values at the significance level of 5% and 10% are −3.45 and −3.15, respectively.
[d] Comparing with 2007–2010.

To obtain the estimators, we can minimize the determinant for the mean squared errors by Eq. (3):

$$\frac{1}{T}\left|\sum_{t=1}^{T}\left(\Delta\boldsymbol{g}_t-\boldsymbol{\zeta}_0-\boldsymbol{\zeta}_1\boldsymbol{g}_{t-1}\right)\left(\Delta\boldsymbol{g}_t-\boldsymbol{\zeta}_0-\boldsymbol{\zeta}_1\boldsymbol{g}_{t-1}\right)'\right|. \tag{7}$$

Replacing $\Delta\tilde{\boldsymbol{g}}_t=\tilde{K}'^{-1}\boldsymbol{\eta}_t$ and $\tilde{\boldsymbol{g}}_{t-1}=\tilde{B}'^{-1}\boldsymbol{f}_t$, and putting them into Eq. (7), we have: $\left|\tilde{K}\right|^{-2}\left|\frac{1}{T}\sum_{t=1}^{T}\left(\boldsymbol{\eta}_t-\Pi\boldsymbol{f}_t\right)\left(\boldsymbol{\eta}_t-\Pi\boldsymbol{f}_t\right)'\right|$, where Π are the coefficients of $\boldsymbol{\eta}_t$ on $\boldsymbol{f}_t$, and $\tilde{K}'\Omega_{11}\tilde{K}=I_n$ with $\left|\tilde{K}\right|^{-2}=\left|\Omega_{11}\right|$. The correlation between $f_{j,\,t}$ and $\eta_{j',\,t}$ is r_j for $j=j'$, and there are zeros for $\forall j\neq j'$.

Using the coefficient of determination for $f_{j,\,t}$ on $\eta_{j,\,t}$ as r_j^2, we have the following relationship:

$$\left|\frac{1}{T}\sum_{t=1}^{T}\left(\boldsymbol{\eta}_t-\Pi\boldsymbol{f}_t\right)\left(\boldsymbol{\eta}_t-\Pi\boldsymbol{f}_t\right)'\right|=\begin{vmatrix}1-r_1^2 & 0 & \dots & 0\\ 0 & 1-r_2^2 & \dots & 0\\ \vdots & \vdots & \ddots & \vdots\\ 0 & 0 & \dots & 1-r_N^2\end{vmatrix}.$$

The value of Eq. (7) equals $\left|\Omega_{11}\right|\prod_{j=1}^{N}\left(1-r_j^2\right)$, which can be expressed by using eigenvalues:

$$\left|\Omega_{11}\right|\prod_{j=1}^{N}\left(1-\lambda_j\right). \tag{8}$$

If we have $N-h$ elements of $\boldsymbol{f}_t$ that are non-stationary, then this implies that their canonical correlations, $r_{h+1}, r_{h+2}, \dots, r_N$, are equal to zero. The above equation can then be rewritten as $\left|\Omega_{11}\right|\prod_{j=1}^{h}\left(1-\lambda_j\right)$. Using the eigenvalue, we can identify whether the factor is stationary or not. In other words, if $\lambda_j>0$, then $f_{j,\,t-1}$ is a stationary process, otherwise, $\lambda_j=0$, indicating a non-stationary process.

3.1. Considering serial correlation

Assume $u_{k,t}$ is associated with an ARMA(p,q) model; that is:

$$\phi(L)u_{k,\,t}=\theta(L)a_{k,\,t}, \tag{9}$$

where $a_{k,\,t}$ is heteroscedastic and follows NID$(0,\sigma_k^2)$. Term L is a lag operator, and the roots of the autoregressive (AR) and moving average (MA) polynomials, $\phi(L)=1-\phi_1L-\phi_2L^2-\ldots-\phi_pL^p=0$ and $\theta(L)=1+\theta_1L+\theta_2L^2+\ldots+\theta_qL^q=0$, are located outside the closed unit circle.

According to Chen (2006), the cross variance and covariance in Eq. (4) can then be expressed as the following:

$$\hat{\Omega}_{11}(\Theta)=\frac{4\pi}{T}\sum_{j=1}^{T^*}Re\left(\frac{F_{\Delta\boldsymbol{g}_t}(\omega_j)\,\bar{F}'_{\Delta\boldsymbol{g}_t}(\omega_j)}{S(\omega_j;\ \Theta)}\right),$$

$$\hat{\Omega}_{22}(\Theta)=\frac{4\pi}{T}\sum_{j=1}^{T^*}Re\left(\frac{F_{\boldsymbol{g}_{t-1}}(\omega_j)\,\bar{F}'_{\boldsymbol{g}_{t-1}}(\omega_j)}{S(\omega_j;\ \Theta)}\right),$$

$$\hat{\Omega}_{12}(\Theta)=\frac{4\pi}{T}\sum_{j=1}^{T^*}Re\left(\frac{F_{\Delta\boldsymbol{g}}(\omega_j)\,\bar{F}'_{\boldsymbol{g}_{t-1}}(\omega_j)}{S(\omega_j;\ \Theta)}\right),$$

where $F_{\Delta\boldsymbol{g}_t}(\omega_j)$ and $F_{\boldsymbol{g}_{t-1}}(\omega_j)$ are the Fourier transforms of $\Delta\boldsymbol{g}_t$ and $\boldsymbol{g}_{t-1}$ at frequency ω_j, respectively, and $S(\omega,\Theta)=|\theta(e^{-i\omega})\phi(e^{-i\omega})^{-1}|^2$ is a spectral density function. We can obtain estimator $\hat{\Theta}$ through a likelihood function and achieve the largest value given by:

$$L(\Theta)=-\frac{TN}{2}\log 2\pi-\frac{T}{2}\log\left|\Omega_{11}(\Theta)\right|-\frac{T}{2}\sum_{j=1}^{N}\log\left(1-\lambda_j(\Theta)\right), \tag{10}$$

where $\lambda_j(\Theta)$ are the eigenvalues of $\Omega_{22}^{-1}(\Theta)\Omega_{21}(\Theta)\Omega_{11}^{-1}(\Theta)\Omega_{12}(\Theta)$ for $j=1$ to N, and $\lambda_j(\Theta)$ can be used to test whether the factor is stationary or not.

If we set a null hypothesis with $H_0: r_{h+1}=r_{h+2}=\ldots=r_N=0$, then this implies that $f_{j,\,t}$ is non-stationary for $j=h+1,\ldots,N$. Here, as the number of non-stationary processes could be large, we use the bootstrap method to calculate the confidence interval and test whether the factor is stationary or not.

Table 4
This table shows the persistent and mean reversion proportions[a] from the common components concealed in the gap between the price and equilibrium for the second-hand housing market between April 2007 and April 2010, before the implication of the housing policies. The numbers of stationary and non-stationary factors are 9 and 10, respectively.

City name	Coefficients[b]		ADF value[c]	Portion of	Type of
	$\hat{\rho}-1$	$\hat{\sigma_\rho}$	$\frac{\hat{\rho}-1}{\hat{\sigma_\rho}}$	sum of squares	series
Beijing	−0.0994	0.0968	−1.0269	0.9005	$\hat{g}^n$
Beijing	−1.2035**	0.274	−4.393	0.0995	$\hat{g}^s$
Tianjin	−0.1322	0.1047	−1.2627	0.7983	$\hat{g}^n$
Tianjin	−1.1664**	0.2805	−4.1578	0.2017	$\hat{g}^s$
Shanghai	−0.1817	0.1177	−1.5442	0.6978	$\hat{g}^n$
Shanghai	−0.9131**	0.2113	−4.3215	0.3022	$\hat{g}^s$
Chongqing	−0.1154	0.0653	−1.7674	0.5796	$\hat{g}^n$
Chongqing	−0.9478**	0.2262	−4.1901	0.4204	$\hat{g}^s$
Guangzhou	−0.1207	0.0835	−1.4448	0.8462	$\hat{g}^n$
Guangzhou	−1.1726**	0.2031	−5.7727	0.1538	$\hat{g}^s$
Wuhan	−0.2816	0.1471	−1.9149	0.7504	$\hat{g}^n$
Wuhan	−1.2463**	0.2596	−4.8013	0.2496	$\hat{g}^s$
Chengdu	−0.1396	0.091	−1.5341	0.7938	$\hat{g}^n$
Chengdu	−1.1668**	0.2513	−4.6428	0.2062	$\hat{g}^s$
Nanjing	−0.0908	0.065	−1.3956	0.8646	$\hat{g}^n$
Nanjing	−1.3112**	0.2823	−4.6451	0.1354	$\hat{g}^s$
Shenyang	−0.6322	0.2073	−3.0503	0.6522	$\hat{g}^n$
Shenyang	−0.8744**	0.2437	−3.5879	0.3478	$\hat{g}^s$
Xian	−0.1389	0.0826	−1.6819	0.4695	$\hat{g}^n$
Xian	−1.2976**	0.2234	−5.8075	0.5305	$\hat{g}^s$
Shenzhen	−0.0824	0.0588	−1.4006	0.8625	$\hat{g}^n$
Shenzhen	−1.1159**	0.2668	−4.1824	0.1375	$\hat{g}^s$
Harbin	−0.6288**	0.1816	−3.4617	0.3471	$\hat{g}^n$
Harbin	−1.1105**	0.2531	−4.3872	0.6529	$\hat{g}^s$
Changchun	−0.6907**	0.1847	−3.7403	0.5001	$\hat{g}^n$
Changchun	−0.8471**	0.2142	−3.9554	0.4999	$\hat{g}^s$
Dalian	−0.0997	0.0893	−1.1169	0.8554	$\hat{g}^n$
Dalian	−1.4555**	0.2739	−5.3132	0.1446	$\hat{g}^s$
Jinan	−0.1382	0.1123	−1.23	0.5583	$\hat{g}^n$
Jinan	−1.0334**	0.263	−3.9296	0.4417	$\hat{g}^s$
Qingdao	−0.103	0.0836	−1.2322	0.903	$\hat{g}^n$
Qingdao	−1.3403**	0.2742	−4.8885	0.097	$\hat{g}^s$
Hangzhou	−0.1067	0.0801	−1.3311	0.7937	$\hat{g}^n$
Hangzhou	−1.2652**	0.2746	−4.6073	0.2063	$\hat{g}^s$
Ningbo	−0.1489	0.1029	−1.4465	0.6948	$\hat{g}^n$
Ningbo	−0.7988*	0.2515	−3.1762	0.3052	$\hat{g}^s$
Xiamen	−0.0866	0.0595	−1.4541	0.9404	$\hat{g}^n$
Xiamen	−1.8458**	0.2182	−8.4604	0.0596	$\hat{g}^s$

where * and ** denote rejection of the null hypothesis at the 5% and 10% significance levels respectively.

[a] The pricing equation is $\log P_t=\hat{\beta}_0+\hat{\beta}_1\log y_t+\hat{\beta}_2 p_{f,t}+\hat{\beta}_3 i_t+\hat{\beta}_4 t+\hat{g}_t$, where $\hat{g}_t=\hat{g}_t^s+\hat{g}_t^n$, and $\hat{g}_t^s$ and $\hat{g}_t^n$ represent the stationary and non-stationary parts, respectively. The proportions are measured by the sum of squares in total, and we use the ADF test to verify the property of the decomposed series, where the best BIC is used for the lag length.

[b] The ADF model is $\Delta g_t=\alpha+(\rho-1)g_{t-1}+\delta_1\Delta g_{t-1}+\ldots+\delta_p\Delta g_{t-p}+a_t$.

[c] The critical values at the significance level of 5% and 10% are −3.45 and −3.15, respectively.

Table 5
The numbers of stationary and non-stationary factors are 10 and 9, respectively. We measure the mean reversion and persisting proportions in the second-hand housing market between January 2011 and February 2015, after the introduction of the housing policies. We compare the results with the situation before the housing policies and find that they were not like the new housing market with obvious effects in most cities.

City name	Coefficients[a]		ADF value[b]	Portion of	Type of	Efficiency
	$\hat{\rho}-1$	$\hat{\sigma_{\rho}}$	$\frac{\hat{\rho}-1}{\hat{\sigma_{\rho}}}$	sum of squares	series	
Beijing	−0.0979	0.0531	−1.8448	0.6751	$\hat{g}^n$	
Beijing	−0.8098**	0.1798	−4.5031	0.3249	$\hat{g}^s$	↑
Tianjin	−0.0032	0.0477	−0.0662	0.8847	$\hat{g}^n$	
Tianjin	−0.8099**	0.1673	−4.8411	0.1153	$\hat{g}^s$	↓
Shanghai	−0.0954	0.0563	−1.6959	0.5974	$\hat{g}^n$	
Shanghai	−0.8062**	0.1798	−4.4844	0.4026	$\hat{g}^s$	↑
Chongqing	0.007	0.055	0.1271	0.6188	$\hat{g}^n$	
Chongqing	−0.4448	0.1445	−3.078	0.3812	$\hat{g}^s$	↓
Guangzhou	−0.014	0.0493	−0.2835	0.6969	$\hat{g}^n$	
Guangzhou	−0.8406**	0.1682	−4.9978	0.3031	$\hat{g}^s$	↑
Wuhan	−0.0159	0.0584	−0.2714	0.6478	$\hat{g}^n$	
Wuhan	−0.605**	0.1589	−3.808	0.3522	$\hat{g}^s$	↑
Chengdu	−0.0279	0.0574	−0.487	0.6791	$\hat{g}^n$	
Chengdu	−0.6991**	0.1779	−3.9295	0.3209	$\hat{g}^s$	↑
Nanjing	−0.0228	0.0465	−0.489	0.7373	$\hat{g}^n$	
Nanjing	−0.7398**	0.1631	−4.5361	0.2627	$\hat{g}^s$	↑
Shenyang	−0.0615	0.0809	−0.7603	0.6355	$\hat{g}^n$	
Shenyang	−0.5859**	0.1661	−3.5275	0.3645	$\hat{g}^s$	↓
Xian	−0.0155	0.0573	−0.2715	0.6422	$\hat{g}^n$	
Xian	−0.6778**	0.177	−3.8299	0.3578	$\hat{g}^s$	↓
Shenzhen	−0.0573	0.0606	−0.9458	0.7188	$\hat{g}^n$	
Shenzhen	−0.6908**	0.177	−3.9034	0.2812	$\hat{g}^s$	↑
Harbin	−0.0064	0.0653	−0.0983	0.6698	$\hat{g}^n$	
Harbin	−0.506*	0.1493	−3.3884	0.3302	$\hat{g}^s$	↓
Changchun	−0.0814	0.0433	−1.8809	0.6208	$\hat{g}^n$	
Changchun	−0.9181**	0.1795	−5.1141	0.3792	$\hat{g}^s$	↓
Dalian	−0.0308	0.0575	−0.5364	0.7117	$\hat{g}^n$	
Dalian	−0.6927**	0.1683	−4.115	0.2883	$\hat{g}^s$	↑
Jinan	−0.0164	0.0622	−0.263	0.588	$\hat{g}^n$	
Jinan	−0.4446	0.1457	−3.0508	0.412	$\hat{g}^s$	↓
Qingdao	−0.0108	0.0539	−0.2009	0.6443	$\hat{g}^n$	
Qingdao	−0.5773**	0.1476	−3.911	0.3557	$\hat{g}^s$	↑
Hangzhou	−0.0278	0.0473	−0.5889	0.7001	$\hat{g}^n$	
Hangzhou	−0.6197**	0.1505	−4.1189	0.2999	$\hat{g}^s$	↓
Ningbo	−0.0341	0.0641	−0.5325	0.6342	$\hat{g}^n$	
Ningbo	−0.6717**	0.1595	−4.2113	0.3658	$\hat{g}^s$	↑
Xiamen	−0.0268	0.0739	−0.3623	0.7157	$\hat{g}^n$	
Xiamen	−0.829**	0.1819	−4.5563	0.2843	$\hat{g}^s$	↑

where * and ** denote rejections of the null hypotheses at the 5% and 10% significance levels.
[a] The ADF model is $\Delta g_t = \alpha + (\rho - 1)g_{t-1} + \delta_1 \Delta g_{t-1} + \ldots + \delta_p \Delta g_{t-p} + a_t$.
[b] The critical values at the significance level of 5% and 10% are −3.45 and −3.15, respectively.

4. Empirical study: the effects of China's housing policies in 2010

In order to control rising prices and make homes more affordable, China's government proposed various restrictions on the housing market in 2010, such as a high down payment for second homes, raising the mortgage rates, and purchase quotas. We are interested in the effects following the implementation of these polices, whether the housing market became more efficient or just pulled back from rising prices. The sample cites cover all cities ranking equal to or higher than the vice-provincial level, i.e., their population is greater than 5 million, including 4 municipalities and 15 vice-provincial cities.[6] The monthly data come from the National Bureau of Statistics of China, and the time period is between April 2007 and February 2015. We separate the data into two periods, April 2007 to April 2010 and January 2011 to February 2015, in which we evaluate the housing policy effects on the new and second-hand housing markets.

Following Eq. (2), we suggest a linear model:

$$\log P_t = \beta_0 + \beta_1 \log y_t + \beta_2 \log p_{f,\,t} + \beta_3 r_t + \beta_4 t + g_t, \tag{11}$$

where P_t is the housing price index for new or second-hand houses, y_t is GDP per capita[7] as a proxy variable for income (unit: US dollar), $p_{f,\,t}$ is the producer price index for production factor price, r_t is the construction loan rate (5 years) as the opportunity cost for investment, and t is trend. If the market is efficient, then capital will flow freely across markets, the price of houses will approach equilibrium, and the gap will exhibit a stationarity; otherwise, the gap possesses a persistent property.

We separate the data into two periods; the first is from April 2007 to April 2010 and the second is from January 2011 to February 2015. We then estimate the housing price equation according to Eq. (11) and then obtain the gaps for all cities, including before and after the policies' implementation.

We use the new house market of Beijing after 2010 as an example. The estimated regression is as follows:

$$\log P_t = 2.9172 + 0.3214 \log p_{f,\,t} + 0.0669 \log y_t - 0.0277 r_t + 0.0004 t + g_t$$

[6] The cities are Beijing, Tianjin, Shanghai, Chongqing, Guangzhou, Wuhan, Chengdu, Nanjing, Shenyang, Xian, Shenzhen, Harbin, Changchun, Dalian, Jinan, Qingdao, Hangzhou, Ningbo, and Xiamen.

[7] As GDP per capita is only provided by quarterly data, we divide the quarterly data into monthly data by using quadratic interpolation.

If market failure exists, then g_t would consist of stationary and non-stationary components. In this estimation, g_t expresses persistence, the statistics of the Durbin–Watson value is 0.048, and the ADF statistic is −1.9268.

After collecting the gaps for all cities, we can estimate the common factors. Assuming there are many factors causing the gap to fluctuate, some of the factors adjust themselves toward equilibrium with a mean reversion characteristic and some fluctuate randomly with a persistent property. If we have N factors, then the process of the jth factor is described as follows:

$$\Delta f_{j,\ t} = (\rho_j - 1) f_{j,\ t-1} + u_t,$$

where $\rho_j \in [0,1]$ and $|\rho_j - 1|$ indicates the adjustment speed. If the magnitude is greater, then the adjustment speed is faster. When $|\rho_j - 1| = 0$, it implies the factor is persistent due to immobility of capital flowing between the housing market and other assets. According to Eq. (5), assume the gap between the housing price and equilibrium is affected by N factors as follows:

$$g_{j,\ t} = \beta_{j,\ 1} f_1 + \beta_{j,\ 2} f_2 + \beta_{j,\ 3} f_3 + \ldots + \beta_{j,\ N} f_N.$$

If capital flows freely, then the housing price will remain stable in relation to the equilibrium. The factors will exhibit mean reversion characteristics. By contrast, if there is market failure, then capital cannot flow freely, the gap will remain persistent and not have a stable relationship, implying the factor is non-stationary.

Following Eq. (3), a one-period lagged model for the China housing market in different cities can be established as:

$$\begin{bmatrix} \Delta g_{1,\ t} \\ \Delta g_{2,\ t} \\ \vdots \\ \Delta g_{N,\ t} \end{bmatrix} = \begin{bmatrix} \zeta_{1,\ 1} & \zeta_{1,\ 2} & \cdots & \zeta_{1,\ N} \\ \zeta_{2,\ 1} & \zeta_{2,\ 2} & \cdots & \zeta_{2,\ N} \\ \vdots & & & \\ \zeta_{N,\ 1} & \zeta_{N,\ 2} & \cdots & \zeta_{N,\ N} \end{bmatrix} \begin{bmatrix} g_{1,\ t-1} \\ g_{2,\ t-1} \\ \vdots \\ g_{N,\ t-1} \end{bmatrix} + \begin{bmatrix} u_{1,\ t} \\ u_{2,\ t} \\ \vdots \\ u_{N,\ t} \end{bmatrix}, \quad (12)$$

where $N = 19$. We note here that $g_{j,t}$ has been detrended and demeaned, thus the intercepts in Eq. (3) can be ignored. After obtaining the common factors, we arrange the factors from the largest to the smallest, according to the sum of squares. Fig. 3 illustrates the 4 largest major factors for new and second-hand housing markets during different periods, where the stationary factors show a mean reversion property fluctuating intensively around zero, which are different from the non-stationary factors with a diffusive characteristic.

According to Eq. (4), we can estimate $\hat{\lambda}_j$ for each component. In order to reduce the bias, we apply the bootstrap method to get the empirical distribution for each $\hat{\lambda}_j$. With 300 times of re-sampling, the boxplot shows the degree of dispersion of $\hat{\lambda}_j$, which can be seen in Fig. 4. We use the confidence interval $(Q_1 - 1.5\Delta Q, Q_3 + 1.5\Delta Q)$ to recognize the stationary and non-stationary factors, where $\Delta Q = Q_3 - Q_1$, and Q_1 and Q_3 represent the first and third quartiles.

We eventually get 10 stationary and 9 non-stationary factors.[8] After recognizing the stationary and non-stationary factors, we measure how the components affect $g_{j,t}$ for each city. For instance, we decompose the gap $g_{j,t}$ for Beijing with the new housing market after 2010 into the stationary and non-stationary factors, which can be represented as follows:

$$g_{Beijing,\ t} = \underbrace{\begin{matrix} 0.0853 f_{1,\ t} + 0.0274 f_{2,\ t} + 0.1022 f_{3,\ t} + 0.0884 f_{4,\ t} + 0.2881 f_{5,\ t} \\ -0.0497 f_{6,\ t} + 0.0034 f_{7,\ t} - 0.0592 f_{8,\ t} - 0.0045 f_{9,\ t} + 0.0791 f_{10,\ t} \end{matrix}}_{\text{stationary}}$$
$$\underbrace{\begin{matrix} -0.0389 f_{11,\ t} + 0.0884 f_{12,\ t} + 0.0195 f_{13,\ t} - 0.0237 f_{14,\ t} + 0.0137 f_{15,\ t} \\ -0.0229 f_{16,\ t} + 0.0152 f_{17,\ t} + 0.2534 f_{18,\ t} + 0.3349 f_{19,\ t} \end{matrix}}_{\text{non-stationary}}.$$

We thus can now measure the proportions of stationary and non-stationary parts for the gap of each city. Tables 2 and 3 show the results of the new housing markets at different periods. We use the ADF test to verify their stationarity and show consistent results. Comparing these two tables, we see the new housing market became more efficient after the housing policies were implemented, with the exception of Jinan. By increasing the holding cost for vacancies, the government's housing policies indeed impacted the market, which made the prices fall faster, therefore easing the gap's persistent situation. For example, when looking at the new housing market before 2010, Beijing's proportions for persistency and mean reversion were 0.7695 and 0.2305, respectively. After 2010, its proportions became 0.619 and 0.381, with the persistent portion decreasing and the mean reversion portion increasing, implying this market became more efficient.

Tables 4 and 5 demonstrate the proportions for the second-hand market at different periods. The results show some differences from the new house market. We find the positive effects on the second-hand market are not as apparent as on the new house market. Comparing Tables 2, 3, 4, and 5, 18 of 19 new house markets in the cities exhibit better performances after 2010 (with the exception of Jinan), which differs from the second-hand housing market in which 11 of 19 cities improved. These results are reasonable from the supply side when we consider the difference between the new and second-hand house markets, because most new houses are sold by construction companies. This is different from second-hand houses that are sold by individuals. A construction company proposes a building plan that usually contains many units; that is, the company usually has more market power on setting price. Further, a construction company also employs a lot of funds on a building project, resulting in time-costly risk exposure that is higher than that of a single seller. These results are also rationalized from the demand side, because new houses usually have higher loan-to-value ratios and quality. Investors commonly favor new houses as an investment target. With various investment alternatives, investors are always more elastic than those who purchase houses to live in. Thus, government policies have a greater influence on these new house markets than on the second-hand house market, which is revealed in the empirical results. For example, Chongqing's new house market initially experienced a high degree of market failure. Its proportion for the persistent part hit a high of 0.8762 before 2010, but after 2010 this proportion fell to 0.7368. This is different from the second-hand market, whose portion of persistency was 0.5796 before 2010, but after 2010 this ratio slightly rose to 0.6188. Due to the above reasons, the government's housing policies have had a huge impact on the new house market rather than on the second-hand market.

We next measure the root of the mean square error (RMSE) for each factor, which expresses the size of the unexpected shocks, and through $\hat{\lambda}_j$ we can calculate the adjustment speed for each factor—that is, $|\rho_j - 1| = \sqrt{\lambda}$.

8 The medians are 0.9321, 0.8718, 0.8109, 0.7551, 0.6987, 0.6392, 0.5768, 0.5079, 0.4384, 0.3523, 0.2519, 0.1490, 0.0705, 0.0180, 0.0021, 0.0000, 0.0000, 0.0000, and 0.0000, respectively.

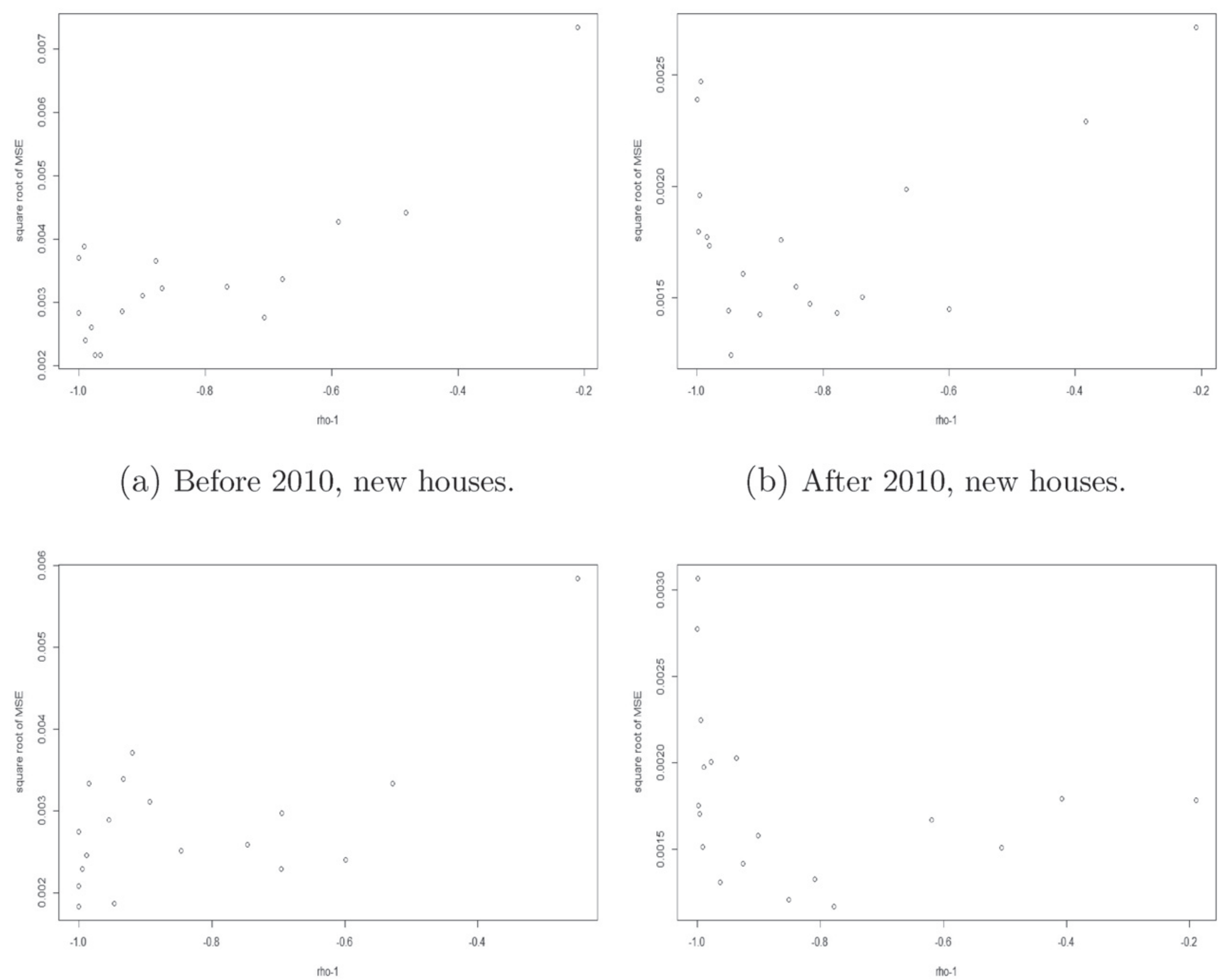
The performance also can be seen in Fig. 5. The left-side figures illustrate the new and second-hand housing markets before 2010 (April 2007–April 2010), and the right-side figures show the markets after 2010 (January 2011–February 2015). Along the horizontal axis, the greater the magnitude of $|\hat{\rho}-1|$ is, the quicker the price is adjusted. In contrast, a small magnitude has more persistence and has a lower adjustment speed.

We find that even for the period before 2010, when the adjusting speed is low (indicating a persistent factor), the factor within the price–equilibrium gap could be highly volatile. For instance, before 2010 the lowest adjustment speed factor in the new housing market had a speed of −0.1665 and RMSE reached a high value of 0.0041. However, after 2010, the lowest speed turned fast, at −0.2083, while RMSE decreased to 0.00272. If RMSE is smaller and the adjusting speed is high, then it implies a less unpredictable transaction cost. Similar results can be seen in the second-hand housing market, where the lowest adjustment factor's speed and RMSE before 2010 were −0.2469 and 0.00565 respectively. After 2010, its speed and RMSE became −0.18949 and 0.00178, where we can see RMSE fell quite largely. This demonstrates that the housing policies certainly affected the two markets.

5. Concluding remarks

This article develops a model to examine the degree of market failure, whereby our model evaluates the new and second-hand housing markets for 19 major cities in China. Considering the persistent and mean reversion characteristics concealed in the gap between price and equilibrium, we analyze panel data with a multiple factor model.

This paper illustrates that a high transaction cost will cause a high probability for market failure. Through the speed of adjustment, we measure the degree of market failure for each city. Comparing the pre- and post-policy shock periods, we discover that the large volatility components at low adjustment speeds became smaller after 2010, meaning the market became more flexible and efficient. This is more obvious on the new housing market than the second-hand market, which led the overall housing market to be more efficient. We examine 19 major cities that rank equal to or higher than the vice-provincial level. Eighteen new house markets have degrees of market failure that are associated with the ratios of the persistent part decreasing. This is illustrated by changes in four municipalities: Beijing's persistent part ratio



(a) Before 2010, new houses.

(b) After 2010, new houses.

(c) Before 2010, second-hand house.

(d) After 2010, second-hand house.

Fig. 5. The left-side figures illustrate the new and second-hand housing markets before 2010 (April 2007–April 2010), and the right-side figures show the markets after 2010 (January 2011–February 2015). Along the horizontal axis, the greater the magnitude of $|\hat{\rho}-1|$, the higher the speed is that the price adjusts. In contrast, a small magnitude shows a more persistent and low adjustment speed. Comparing to the time before 2010, more factors are located at the high-speed adjustment zone (close to −1) after the housing policies in 2010.

decreases from 0.7695 to 0.6169, Shanghai's from 0.7397 to 0.5694, Tianjin's from 0.8358 to 0.6696, and Chongqing's from 0.8762 to 0.7368. This significantly demonstrates that performance improved after 2010.

According to the National Bureau of Statistics of China, the major cities' ratios of house prices to earnings are higher than those of other countries. For example, Beijing's ratio of house prices to earnings is 19.1, far higher than London's 9.2. It is difficult for an average-income Chinese resident to afford such high house prices. As housing expenditures occupy a high ratio of income, an ordinary person can hardly save any money, thus enlarging wealth inequality. We show that policies in 2010 did improve the house market's efficiency, preventing housing prices from soaring and helping residents to buy houses at reasonable prices. Thus, if the Chinese government can extend these policies to other areas to include not only big cites, but also entire provinces, even if the economic growth is slowing down, these policies will make the economic system healthier.

Appendix A. This table shows the definitions of the used symbols, variables, and data resources

Table A1
This table shows the definitions of the used symbols, variables, and data resources.

Symbol	Description	
V	Value function	
t	Time index	
N	Total city number	
T	Time length	
u_t	Disturbance	
H_t	Capital in terms of dollars invested in the housing market	
W_t	Capital in terms of dollars invested in other assets	
c_t	Consumption at time t	
I_t	Cumulated funds transferred from other assets into housing markets	
D_t	Cumulated funds outflowed from housing market into other assets	
α	Depreciation rate of house	
ν	Appreciation (growth) rate of capital in housing	
μ	Appreciation (growth) rate of capital in other asset	
θ	Transaction cost	
dz_t	Difference of Wiener process	
σ_w	Standard deviation of other asset	
k	Boundary of the rate of H_t/W_t beginning to flow	
τ	Discounting rate	
γ	Power of utility	
ρ_j	Autocorrelation coefficient for jth factor	
$\boldsymbol{g}_t$	Gap between price and equilibrium	
Ω_{11}	Variance–covariance matrix of $\Delta\boldsymbol{g}_t$	
Ω_{22}	Variance–covariance matrix of $\boldsymbol{g}_t$	
Ω_{12}	Cross covariance matrix of $\Delta\boldsymbol{g}_t$ and $\boldsymbol{g}_t$	
λ_j	Eigenvalue for jth factor	
B	Eigenvector for $\boldsymbol{g}_t$	
K	Eigenvector for $\Delta\boldsymbol{g}_t$	
f_t	Factor transformed from $\boldsymbol{g}_t, f_t = [f_{1,t}, f_{2,t}, \ldots, f_{N,t}]$	
η_t	Factor transformed from $\Delta\boldsymbol{g}_t, \eta_t = [\eta_{1,t}, \eta_{2,t}, \ldots, \eta_{N,t}]$	
r_j	Correlation between f_j and η_j	
ς_0, ς_1	First- and second-order of autoregressive coefficients for gap g_t	
Variable	Description	Source
P_t	House selling price index for new and second-hand residential buildings by city, China, corresponding period of the previous year (CPPY) = 100.	National Bureau of Statistics of China
y_t	Gross domestic product, per capita, China, unit: USD.	Oxford Economics
r_t	Construction loan rate (5 years), China, unit: percentage.	The People's Bank of China
p_f	Producer price index, CPPY = 100.	National Bureau of Statistics of China

Appendix B. Considering a constant relative risk aversion utility function for illustration, where we let:

$$U(c_t,\ H_t) = \frac{c_t^{\gamma}}{\gamma} + \frac{H_t^{\gamma}}{\gamma}.$$

Assume consumption occupies a fixed ratio of the other assets where $c_t = \beta W_t$. Here, β is the rate of consumption in capital stock and equals marginal production of capital times consumption propensity. According to Eq. (1) and presuming $V = AH^{r-s}W^{s}$, we take a complementary function and particular integral to obtain the solution of the differential equation. We thus have the value function.

$$\begin{aligned} V(H_t,\ W_t;\ \alpha,\ \beta,\ \tau,\ \gamma) &= \left[\frac{1}{\tau-(\nu-\alpha)\gamma}\right]\frac{H_t^{\gamma}}{\gamma} \\ &+ \left[\frac{1}{\tau-\frac{1}{2}\sigma^2\gamma^2-\left(\mu-\beta-\frac{1}{2}\sigma^2\right)\gamma}\right]\frac{(\beta W_t)^{\gamma}}{\gamma} \\ &+ A_1 H_t^{\gamma-s_1} W^{s_1} + A_2 H_t^{\gamma-s_2} W^{s_2}, \end{aligned}$$

where s_1 and s_2 are the roots of:

$$\frac{1}{2}\sigma^2 s^2 + \left(\alpha - \nu + \mu - \beta - \frac{1}{2}\sigma^2\right)s + (\nu - \alpha)\gamma - \tau = 0.$$

We can then obtain the marginal products as follows:

$$V_H = \frac{H_t^{\gamma-1}}{\tau - (\nu - \alpha)\gamma} + (\gamma - s_1)A_1 H_t^{\gamma - s_1 - 1} W_t^{s_1} + (\gamma - s_2)A_2 H_t^{\gamma - s_2 - 1} W_t^{s_2} \text{ and}$$
$$V_W = \frac{\beta^\gamma W_t^{\gamma-1}}{\tau - \frac{1}{2}\sigma^2\gamma^2 - \left(\mu - \beta - \frac{1}{2}\sigma^2\right)\gamma} + s_1 A_1 H_t^{\gamma - s_1} W_t^{s_1 - 1} + s_2 A_2 H_t^{\gamma - s_2} W_t^{s_2 - 1}.$$

If the rate of H_t/W_t falls outside of the range of $(k, 1/k)$, then capital begins flowing. In the case of $H_t/W_t > 1/k$, capital begins flowing away from the housing market into other assets—that is:

$$dH_t = (\nu - \alpha)H_t dt - dD_t \text{ and}$$
$$dW_t = W_t(\mu - \beta)dt + (1 - \theta)dD_t + W_t\sigma_W dz_t.$$

If $H_t/W_t < k$, then capital begins flowing into the housing market:

$$dH_t = (\nu - \alpha)H_t dt + (1 - \theta)dI_t \text{ and}$$
$$dW_t = W_t(\mu - \beta)dt - dI_t + W_t\sigma_W dz_t.$$

We simply assume $k = 1 - \theta$ to represent the relationship between the transaction cost and liquidity property of capital.

Appendix C. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.econmod.2016.03.024.

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