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Original Research Article

Are Common Factors the Main Drivers of House Market Boom in China? A Short- and Long-Term Perspective

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Abstract: This paper investigates the house price dynamics across 30 regions in China and explores whether common factors or regional factors are the main drivers of house market movements from a short- and long-term perspective. From a short-term perspective, we employ a dynamic factor model and reveal the common factors to be the main drivers, especially in high-growth regions. This is consistent with the conclusion of long-run house price convergence test. Our results also underscore the need for targeted monetary policies, particularly in high-growth regions, to maintain the stability of house market in China.

Keywords: Common factors; Regional factors; Monetary policies; Club convergence.

1. INTRODUCTION

The house price dynamics have attracted growing attention from researchers and policymakers over the last decades. From a short-term perspective, extensive studies have been conducted to investigate the nature and extent of regional house price comovements (Del Negro *et al*., 2007; Stock and Watson, 2008; Merikas *et al*., 2012, etc.). Understanding the nature, magnitude, and principal driving forces underlying the comovement also holds significant implications for policymakers to design house market polices (Engle *et al*., 1985; Bernanke *et al*., 2005; Goodhart and Hofmann, 2007; Forni and Gambetti, 2010; Huang *et al*., 2016). If house price movements are predominantly driven by national-wide factors, policymakers may opt to formulate national-level policies, such as monetary policies. Conversely, if regional factors exert a more substantial influence, policymakers would need to tailor housing policies with a regional focus. In this context, discerning the relative importance of common factors vis-à-vis regional factors becomes a pivotal issue.

This issue also holds for policymakers from a long-run term perspective since the short-term comovement in house prices does not necessarily imply the existence of its long-term convergence. According to traditional theory, the convergence of house prices is driven by the convergence of fundamentals, such as per capita income (Barro and Sala-i-Martin, 1992; Miles, 2015). However, if the house price boom is mainly driven by bubbles rather than fundamentals, house prices will gradually diverge over time unless all regions happen to be equally affected by bubbles. In this sense, testing house prices' convergence serves as an effective way to understand the house price boom (Zou and Zhou, 2007; Kim and Jeffrey. 2012; Andrew and Glauco, 2013; Zhang and Morley, 2014; Beylunioglu *et al*., 2020).

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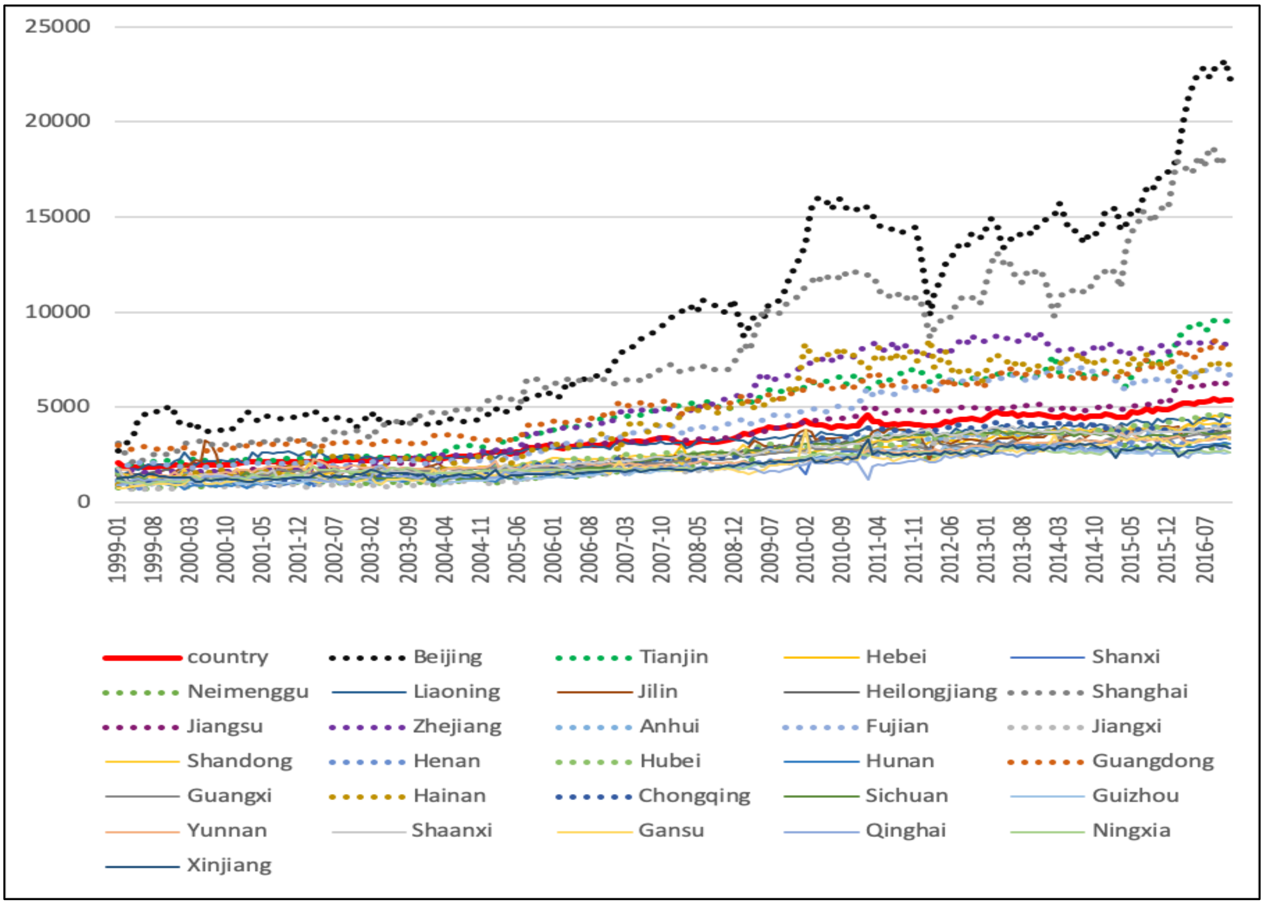

Figure 1: Comovement of regional house prices in China

The house market in China provides a pertinent research context due to its pronounced regional diversities. Figure 1 and Figure 2 depicts the comovement and the regional heterogeneity of house prices in China, respectively. With the national average annual growth rate at 7.99%, the highest growth rate of 11.64% in Shanghai is nearly three times higher than the lowest growth rate in Xinjiang. This indicates that the house price boom may not be a national-wide phenomenon. Therefore, the analysis of the effects of monetary policy on house market, relying solely on the national average of house prices, may result in potentially misleading insights.

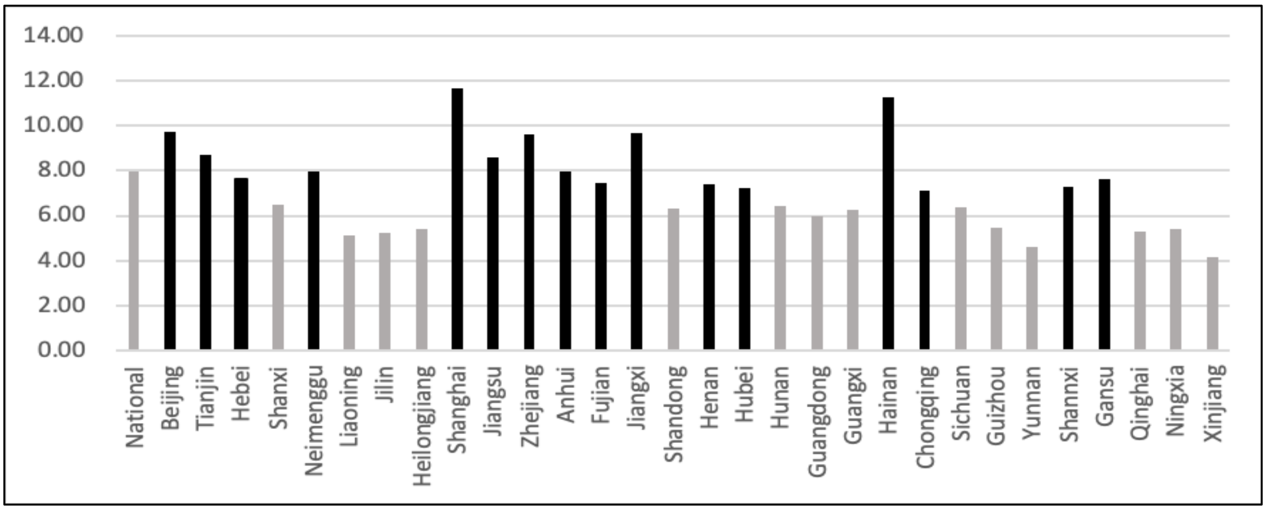

Figure 2: Average annual growth rates of regional house prices in China

Note: The vertical axis represents average annual house price growth rate (%) and the horizontal axis represents the 30 regions in China. The bold regions are high growth regions while the others are low growth regions. All growth rates are calculated by the authors.

This paper aims to investigate the house price dynamics in China from a short-term and long-term perspective, mainly focusing on the relative importance of common factors vis-à-vis regional factors. Specifically, this paper tries to answer the following three questions: (1) are common factors the main drivers of the house price boom in China? (2) are common factors the main drivers of the house price movements in both high- and low- growth regions? (3) what are the effects of monetary policy on the common factors in house price dynamics?

In order to answer the first two questions from a short-term perspective, this paper estimates a dynamic factor model proposed by Stock and Watson (1989, 2002) to identify common factors and regional specific factors in house prices. Our results reveal the common factors to be the main drivers, especially in high-growth regions. To test the effects of monetary policy, we employ a factor-loading VAR model and observe more prolonged and stronger impacts on common factors, relative to the impacts on national house prices.

In the analysis from a long-term perspective, we perform the *log t* convergence test proposed by Phillips and Sul (2007) for 30 regions in China, with a finding favor of club convergence. However, the club members of house price convergence are found to exhibit significant differences when compared to those of regional GDP convergence, implying that the convergence of regional house prices are not driven by regional fundamentals. This is consistent with our findings from short-term perspective that common factors are the main drivers to the house price boom.

This paper contributes to the house price dynamics literature in several aspects. Firstly, it offers new insights by exploring whether common factors or regional factors are the main drivers, which has not been fully investigated previously. To the best of our knowledge, this is the first paper to empirically test their relative importance from both short-term and long-term perspectives. Secondly, it is also the first paper to carry out the investigations in high-growth vs. low-growth regions. Lastly, the finding of stronger impacts of monetary policy on common factors sheds some lights on a potential new proxy, which may replace national average, for house price movement in future research.

The remainder of this paper is organized as follows. Section 2 provides a brief review of previous literature on house price dynamics. Section 3 describes the data and introduces the methodology. The empirical results are reported in Section 4 and discussed in Section 5. Section 6 and 7 presents the implications and limitations. Finally Section 8 concludes the paper.

2. LITERATURE REVIEW

Previous literature on house price dynamics has primarily focused on comovement from a short-term perspective and convergence from a long-term perspective. In this sense, this section will review related studies based on these two topics.

2.1. Comovement of House Prices

The seminal theoretical research from Engle *et al*., (1985) estimates dynamic factor models and identifies a few latent common factors in the movement of house prices. As more elaborated dynamic factor models are developed (e.g. Stock and Watson, 1989, 2002, etc.), more studies utilize dynamic factor models to analyze cross-country or cross-regional movement of house prices, as well as its causes. Otrok and Trrones (2005) estimate a dynamic factor model to examine both the comovement of house prices across developed countries and the relationship between the movement of house prices and the fluctuations of macroeconomic aggregates. They identify four components (global, variable-specific, country-specific and idiosyncratic component) in the comovement of the 91 time series and reveal the common dynamic component in interest rate to be the main resource for the comovement of house prices and macroeconomic variables.

Negro and Otrok (2007) use a dynamic factor model estimated via Bayesian methods to investigate the comovement of house prices in USA. They identify three components (national, regional and stat-specific component) in the movement of house prices and find that the house price movement is mainly driven by the regional specific factors. Stock and Watson (2008) estimate a dynamic factor model to investigate the changes over time in the volatility of building permits and identify a national factor, a regional factor, and a state-specific disturbance in the building permits in the USA. They modify the dynamic factor model proposed by Geweke (1977) to allow for stochastic volatility in the factors and the idiosyncratic disturbances. They find that the movement of building permits is mainly driven by national factors. There is also a growing literature investigating the comovement of house prices beyond the scope of dynamic factor model analysis (Case *et al*., 2000; Kallberg *et al*., 2014, etc.). Merikas *et al*., (2012) use cointegration approach and VAR system to examine house price comovement in the Eurozone economies. They provide a strong evidence of the importance of local factors (especially the interest rate) on the comovement of house prices.

In the case of China, Chiang (2014) uses a cointegration estimation approach to investigate the comovement of regional house prices of six first-tier cities in China over the period 2003-2013. He finds that the ripple effect is characterized by a lead-lag relationship and the main source of housing price appreciation is Beijing. Wengand Gong

(2016) investigated price comovement and volatility spillover effects in China`s house markets over the period 2005-2014. They apply a DSP-GJR-GARCH model to examine whether volatility spillover effects exist and what drives the movement in regional house prices in China. They find that the comovement of house prices is significantly affected by population, income, and national macroeconomic situation. Zhang *et al*., (2017) use a coefficient heterogeneity model with panel data and VAR model to investigate the ripple effect of house prices between 35 cities in China. They find that the North China and East China as well as the regions with higher economic development level are the resources where a ripple effect is from. However, limited literature investigate the comovement beyond the scope of ripple effect. Huang *et al*., (2015) use a dynamic hierarchical model proposed by Moench *et al*., (2013) to investigate the comovement of city-level house prices on data from 2005 to 2014 in China. They identify four components (common, block-specific, sub-block-specific, and idiosyncratic factor) in the movement of house prices. They find that city-specific factors account for a large proportion of house price variations, although the national factors were also important in the post-2009 period.

2.2. Convergence of House Prices

The concept of convergence is an important issue in the field of neoclassical theories, which assumes that the developing countries will catch up with developed countries as the developing countries have a relatively higher economic growth rate. Due to the significant effect of house price dynamics on the real economic activity and household welfare, substantial literature works on the cross-regional convergence of regional house prices. The seminal theoretical research from Mills (1964) and Roback (1982) suggest that the regions with a lower price level tended to have higher growth rates, thereby leading to a long-term convergence. But considering the heterogeneity and local characteristics across regions, it is hard to find such kind of convergence. Barro and Sala-i-Martin (1991, 1992) suggest that there may exist conditional convergence, where clubs of regions share similar economic properties. Phillips and Sul (2007) propose a new convergence test method, log *t* convergence test, arguing that the rejection of absolute convergence does not necessarily mean divergence, because there may exist club convergence.

Substantial research has investigated the regional difference and cross-sectional convergence of house prices since the beginning of the 1990s, especially in major industrial countries. For the UK, MacDonald and Taylor (1993) use regression based cointegration method proposed by Engle-Graner (1987) and multivariate cointegration method proposed by Johansen (1989) to investigate the long-run equilibrium relationships of interregional house prices. They find strong evidence of cointegration relationship among regional house prices. A subsequent research from Cook (2003) applies an extension form of Dick-Fuller test taking account of asymmetric adjustment, provides an evidence of long-run convergence and suggests that the inconsistent results from previous analysis can attribute to an ignored underlying asymmetry in the adjustment process. Holmes (2007) uses three methods (standard ADF unit root tests, panel data unit tests, and SURADF procedure) to reveal the convergence of the majority of UK regions. He also provides evidence of heterogeneity in the regional speeds of adjustment towards long-run equilibrium. Holmes and Grimes (2008) apply unit root test of the first principal component based on regional-national house prices differentials. In addition to the finding that all UK regional house prices are driven by a single common stochastic trend, they also observe that the regions more distant from London exhibit the highest degrees of persistence with respect to deviations in house price differentials. However, a recent research from Abbott and De Vita (2013) use a pairwise approach and find little evidence of long-run convergence.

There are also many studies investigating the convergence of regional house prices in the USA. Clark and Goggin (2009) perform principal component analysis to estimate two latent factors but find mixed evidence of convergence, with little for the first latent factor and some examples of relative convergence within the second latent factor. Holmes *et al*., (2011) use pair-wise approach and find the convergence across U.S. states and Metropolitan areas. Employing fractional integration and cointegration techniques, Apergis and Payne (2012), Kim and Rous (2012), Montanes and Olmos (2013), and Wood *et al*., (2015) use the log-t convergence methodology to investigate the housing price convergence in panels of US states, they provide consistent evidence of absence of overall convergence and strong evidence in favor of club convergence across US states.

In the case of China, most existing literature investigate the regional house price convergence based on the geographic locations of regions, such as economic zones (Eastern, Central, and Western). For instance, Chen and Wang (2000) use ADF unit root tests and cointegration approach to examine the long-run relationship among the house prices of Eastern, Central, and Western regions in China. They find little evidence of overall convergence among house prices in China. Wei and Yang (2007) and Chen and Huang (2010) use cointegration tests to examine the dynamic house prices of Yangtze River Delta and Pearl River Delta respectively.

Limited research look at the convergence of China`s regional house price without focusing on the geographic locations. Fang and Bruce (2014) apply a standard panel unit root test to examine the convergence and find little evidence. On the data of Sales Price Indices from China over the sample period 2001-2013, Rui *et al*., (2015) use the log t convergence test and provide evidence of club convergence instead of overall convergence. They also suggest that the clubs are different from the conventional definitions of economic zones. Inconsistent with their results, Meng *et al*., (2015) use box clustering method, partial correlation method and decomposition of correlation matrix method to elaborate similar clubs with 2005-2013 house price data.

3. DATA AND METHODOLOGY

3.1. Data Description

The house price data used in this paper are urban resident house prices excluding commercial house prices. Different from previous studies using house price index, we construct data set of house prices by total sales amount and total sales area [1]. The raw data of total sales amount, total sales area, and CPI are obtained from *China`s statistical Yearbooks* and the *Wind Database.* Specifically, we use the monthly data from 30 regions [2] in China covering the period 1999:01~2016:12.

We obtain the annual data of GDP from *the official database of the National Bureau of Statistics of the China.* The annual GDP deflators of 30 regions are collected from *the Wind database.* This paper will be working on the real GDP over the period 1979~2016, which will be divided into two subsample periods to explore the convergence in regional real GDP.

It is worth noting that the Chinese New Year holiday may lead to missing data in January, February or both. Considering the proportion of missing data is quite small in the full dataset, we apply a smoothing process [3] to impute the missing data. This paper deflates the regional house prices and national industrial production index by regional and national CPI respectively. In consideration of seasonal effects, all economic activities and prices are seasonally adjusted using the Census X-12 ARIMA method.

3.2. Methodology

The main purpose of this paper is to investigate the short- and long- term movement of regional house prices in China. Therefore, we will introduce dynamic factor model and log-t convergence test [4] in this section.

3.2.1 Dynamic Factor Model

Following Stock and Watson (1989), the distinct feature of a dynamic factor model is that the comovement of an N-dimensional vector of time-series variables (y_t) are driven by a few latent dynamic factors (f_t) and a vector of mean-zero idiosyncratic disturbances (ε_t). These idiosyncratic disturbances arise from measurement error and from local specific features of each individual series. The DFM is defined as Equation (3) ~-(5) as follows

$$y_{it} = c_i + \lambda_{i1} f_{1t} + \lambda_{i2} f_{2t} + \cdots \lambda_{iP} f_{Pt} + u_{it}, i = 1,2, \cdots n \text{ .... (1)}$$

$$f_{pt} = \varphi_{p1} f_{pt-1} + \varphi_{p2} f_{pt-2} + \cdots + \varphi_{pq_f} f_{pt-q_f} + \eta_{pt}, p = 1,2, \cdots P \text{............ (2)}$$

$$u_{it} = \rho_{i1} u_{it-1} + \rho_{i2} u_{it-2} + \cdots + \rho_{iq_u} u_{it-q_u} + \varepsilon_{it} \text{ .... (3)}$$

Where y_{it} is the house price growth rate of i^{th} region. As equation (1) shows, the house price growth rate is determined by common factor f_{pt},, idiosyncratic factor u_{it} and constant term c_i. The loading coefficient λ_{iP} of common factor can be different across regions, since the impact of common factor may be quite different across regions. It is worth to note that the common factor does not necessarily mean national wide fundamental determinants of regional house prices. Nonetheless, the common factor is highly likely to reflect national wide fundamentals as house price bubbles typically concentrate on specific regions. Common factor f_{pt} and idiosyncratic factor u_{it} are mutually and serially uncorrelated. It is assumed by equation (2) and (3) that the common factor and idiosyncratic factor follow AR (q_f) and AR (q_u) stochastic processes respectively. η_{pt}~i.i.d.N $(0,\sigma_\eta^2)$, ε_{it}~i.i.d.N $(0,\sigma_\varepsilon^2)$ and there is no correlation between η_{pt} andε_{it}. The coefficient vector $\theta_i = \{c_i, \lambda_{i,}\rho_i\}$ will be estimated by Gaussian MLE method via Kalman filtering algorithm[5].

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[1]House price= Total sales amount/Total sales area, the unit is yuan/m^2.

[2]Hong Kong, Macao and Tibet are excluded due to the availability of data.

[3]In case of missing January data, we take the mean value of previous month (December) and next month (February). In case of missing February data, we take the mean value of previous month (January) and next month (March), In case of missing both month data, firstly, we calculate the mean value of next two months (March and April) to get the value of February, then we take the mean value of value of December and February to get the value of January.

[4]Please see Geweke (1977), Engle and Watson (1981, 1985), Stock and Watson (1989, 2002, etc.), Bai and Ng (2002, 2006, etc.) and Phillips and Sul (2007, 2009) for more details.

[5]Kalman filtering algorithm has been deeply studied and widely used in these decades (e.g. Schweppe (1965), Pagan (1975), Chow (1975), Taylor (1970), Engle and Watson (1981) etc.).

3.2.2 Log-t Convergence Test

According to Phillips and Sul (2007, 2009), house price P_{it} can be defined as follows:

$P_{it} = \left(\delta_i + \frac{\varepsilon_{it}}{P_t}\right) P_t = \delta_{it} P_t$ …………… (4)

Where $P_{it} = lnHP_{it}$, P_t is the common trend component, δ_{it} is a time-varying loading coefficient, which could be explained as the economic distance to common trend component, ε_{it} is the heterogeneous specific exogenous shock. Here we will be working on δ_{it}, for this, we adapt h_{it} (relative transition coefficient) excluding the common trend component P_t.

$h_{it} = \frac{P_{it}}{\frac{1}{N}\sum_{i=1}^{N} P_{it}} = \frac{\delta_{it}}{\frac{1}{N}\sum_{i=1}^{N} \delta_{it}}$ ………………….. (5)

Where h_{it} has a similar economic mean with δ_{it} that economic distance to common trend component, but the difference is that h_{it} is the relative transition path traces out an individual trajectory for each individual relative to panel average. And we define the cross-sectional variance of relative transition coefficient h_{it} as follows.

$H_t = \frac{1}{N}\sum_{i=1}^{N}(h_{it} - 1)^2$ …………………. (6)

Where $\frac{1}{N}\sum_{i=1}^{N} h_{it} = 1$. When h_{it}→1, H_t→0, it could be interpreted that regional house prices convergence to common trend path.

In order to perform the convergence test, we assume δ_{it} as follows.

$\delta_{it} = \delta_i + \eta_{it}\phi_{it}$ ………………… (7)

$\eta_{it} = \frac{\eta_i}{A(t)t^{\alpha}}, t \geq 1, \eta_i > 0$ …………… (8)

Where ϕ_{it} is *iid* (0, 1) across i with a finite moment, and $A(t)$ is a slowly increasing function for which $A(t) \to \infty$ as $t \to \infty$. $A(t)$ is assumed to be $\ln t$ and α is the speed of the time-varying function.

According to Phillips and Sul (2007, 2009), the conditions whether δ_{it} converges or not could be assumed as follows:

$\operatorname*{plim}_{k\to\infty} \delta_{it+k} = \delta$ if and only if $\delta_i = \delta$ and $\alpha \geq 0$ …………….. (9)

$\operatorname*{plim}_{k\to\infty} \delta_{it+k} \neq \delta$ if and only if $\delta_i \neq \delta$ and $\alpha < 0$ ………………….. (10)

Under the above conditions, the null hypothesis of convergence can be written as follows:

H0: $\delta_i = \delta$ and $\alpha \geq 0$ ………………….. (11)

And then the alternative hypothesis can be written as:

H1: $\delta_i \neq \delta$ and $\alpha < 0$ …………… (12)

as t→∞, h_{it}→1 and also H_t→0, there would be a convergence, in other words, the null hypothesis will not be rejected. Then compute a robust t-statistic ($t_{\hat{\gamma}}$) through the following regress function:

$\log\left(\frac{H_1}{H_t}\right) - 2\log A(t) = \beta + \gamma \log t + u_t$ ………………. (13)

Where γ=2α, so the null hypothesis H0: δ_{it}=δ and α≥0 could be replaced by H0:γ≥0. According to the hypothesis, we run a one-sided robust t-test, if $t_{\hat{\gamma}}$ is larger than -1.65, the null hypothesis cannot be rejected, which implies there is convergence. In contrast, if $t_{\hat{\gamma}}$ is less than -1.65, the null hypothesis is rejected, this does not necessarily imply overall divergence, since there may exist club convergences across regions. There are four steps are needed to test the club convergence, the details can be found in Phillips and Sul (2007).

4. EMPIRICAL RESULTS

4.1. Comovement of Regional House Prices

We begin this section by examining the relative importance of common factors and regional specific factors in the house price movement, followed by a factor-loading VAR model estimation to evaluate the effect of monetary policy on the common factor.

4.1.1. Dynamic Factor Analysis of Regional House Prices

The current dynamic factor model can work well only when the time series is stationary. Therefore, we perform unit root tests of regional house price growth rates and present the results in Table 1. Two sets of unit root tests are reported in the table, with unit root test of single time series in Panel A and panel unit root test in Panel B. In the case of single time series unit root test, we use the Augmented Dicky-Fuller (ADF) test [6] and Phillips-Perron (P-P) tests [7]. Both tests show that the null hypothesis (H0: has unit root) is rejected at the significance level 1%, confirming that the time series of house price for all regions are stationary. We use three panel unit root tests: LLC [8], Breitung [9], and IPS [10] and all of them show that the panel data is stationary.

Table 1: Unit root tests

Panel A Time series unit root test		
Region	**House price growth rate**	
	ADF	**P-P**
Beijing	-3.403***	-3.884***
Tianjin	-3.579***	-3.616***
Hebei	-6.056***	-5.399***
Shanxi	-7.271***	-7.241***
Neimenggu	-6.942***	-6.829***
Liaoning	-6.936***	-7.026***
Jilin	-5.610***	-4.624***
Heilongjiang	-6.323***	-6.154***
Shanghai	-3.626***	-3.882***
Jiangsu	-4.002***	-4.094***
Zhejiang	-2.892**	-3.375***
Anhui	-4.553***	-4.538***
Fujian	-3.793***	-3.790***
Jiangxi	-5.249***	-5.436***
Shandong	-5.401***	-8.045***
Henan	-5.052***	-5.277***
Hubei	-6.829***	-6.899***
Hunan	-6.631***	-6.369***
Guangdong	-4.310***	-5.768***
Guangxi	-5.023***	-6428***
Hainan	-4.628***	-4.646***
Chongqing	-5.652***	-6.026***
Sichuan	-3.740***	-5.274***
Guizhou	-4.344***	-5.485***
Yunnan	-7.271***	-7.235***
Shaanxi	-6.830***	-7.376***
Gansu	-6.426***	-6.303***
Qinghai	-6.315***	-6.262***
Ningxia	-4.274***	-4.268***
Xinjiang	-6.262***	-6.243***
National	-4.229***	-4.261***
Panel B Panel unit root test		
LLC	-9.079***	
Breitung	-10.743***	
IPS	-26.650***	

Note: *, **, *** indicate significance at 10%, 5% and 1% level, respectively.

[6] Dickey, David A., and Wayne A. Fuller. "Distribution of the estimators for autoregressive time series with a unit root." *Journal of the American statistical association* 74, no. 366a (1979): 427-431.
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Given the stationary of time series of regional house prices, we can estimate the models and identify the common factors and regional specific factors. In consideration of the efficiency of the estimation, we select the lags of both AR (q_f) and AR (q_u) as 1, thereby we can minimize the number of estimated parameters.

Table 2 reports the estimation results of dynamic factor analysis. For full sample, the AR coefficient of the common factor is 0.963 and statistically significant at 1% significance level. All the factor loading coefficients (λ_i) are also statistically significant. The null hypothesis of the Wald test ($\lambda_{ip} = 0, i = 1, \cdots n; p = 1, \cdots P$) is also rejected at the significance level of 1%, which indicates that the model is estimated precisely. The loading coefficients (λ_i) represents the sensitivity of house price growth to common factor. High value of λ_i implies that the impacts of changes in common factors pass through more to regional house prices, implying that house prices and possible economic structures of those regions are more tightly connected with national economy.

The values of the factor loading coefficients for 30 regions range from 1.023 to 3.058. We divide regions into two groups based on their average annual growth rates as shown in Figure 2. Regions with growth rate higher than 8% (the national average) are classified as high-growth regions and labelled as bold in Table 2 while the rest are classified as low-growth regions. Comparing with the low-growth regions, the values of λ_i in high-growth regions are almost higher by a factor of 1.9, such as Beijing (2.937), Shanghai (2.425), Jiangsu (2.658), Zhejiang (3.058), Anhui (2.836), Jiangxi (2.864), Guangdong (2.997) etc. In the case of low-growth regions, excluding a few regions [[11]], the values of λ_i are relatively low. Note that the regions with high growth of house prices are relatively more economically developed area than other regions, except Hainan which is a tourist province. Guangdong, Sichuan, and Hunan are relatively developed regions with high house price level even though they belong to the low-growth regions. Thus, the results imply that house prices of the developed regions are more sensitive to changes in common factor.

We evaluate the factor loading coefficients and we find that, in general, the factor loading coefficients are relatively higher in high-growth regions than in low-growth regions. However, the impacts of common factor on movements of regional house prices are determined by variability of factor itself in addition to the values of the factor loading. In order to examine the relatively importance of common factor and regional specific factor as driving forces of the movement of regional house prices, we implement the variance decomposition of regional house price growth rates. The variance of house price growth rate is defined as follow.

Table 2: Estimation results of common factor

Regions	**Full sample**		**Excluding Beijing and Shanghai**	
	$\boldsymbol{\lambda_i}$	**Var-D**	$\boldsymbol{\lambda_i}$	**Var-D**
Shanghai	2.425***	0.807	-	-
Hainan	1.624**	0.656	1.093***	0.355
Beijing	2.937***	0.849	-	-
Jiangxi	2.864***	0.675	2.927***	0.678
Zhejiang	3.058***	0.875	3.011***	0.872
Tianjin	1.309***	0.778	1.284***	0.777
Jiangsu	2.658***	0.828	2.764***	0.838
Anhui	2.836***	0.756	2.926***	0.760
Neimenggu	1.627***	0.356	1.637***	0.356
Gansu	2.349***	0.469	2.298***	0.465
Hebei	1.378***	0.527	1.313***	0.524
Fujian	1.972***	0.786	1.984***	0.786
Henan	2.729***	0.656	2.607***	0.650
Shaanxi	2.135***	0.509	2.152***	0.508
Hubei	1.987***	0.479	2.066***	0.486
Chongqing	2.219***	0.729	2.266***	0.730
Shanxi	1.504***	0.345	1.459***	0.342
Hunan	2.490***	0.549	2.503***	0.549
Sichuan	2.402***	0.684	2.436***	0.685
Shandong	1.660***	0.293	1.711***	0.297
Guangxi	1.941***	0.518	1.896***	0.507
Guangdong	2.997***	0.674	3.140***	0.678
Guizhou	2.111***	0.612	2.209***	0.618

[11] Such as Hunan (2.490), and Guangdong (2.997).

Regions	Full sample		Excluding Beijing and Shanghai	
	λ_i	Var-D	λ_i	Var-D
Heilongjiang	1.318***	0.458	1.284***	0.455
Ningxia	1.462***	0.713	1.329***	0.708
Qinghai	1.023**	0.461	1.044**	0.461
Jilin	1.882**	0.667	1.724**	0.665
Liaoning	1.345***	0.412	1.366***	0.413
Yunnan	1.377***	0.414	1.456***	0.418
Xinjiang	1.631***	0.486	1.677***	0.488
Wald statistics	12689.37***	-	10976.10***	-

Note: *, **, *** indicate significance at 10%, 5% and 1% level, respectively. The bold regions are high growth regions while the others are low growth regions.

$var(y_{it}) = \lambda_i^2 var(f_t) + var(u_{it})$…………………… (14)

The contribution of common factor to the fluctuation of house price growth rate can be defined as follows.

$\frac{\lambda_i^2 var(f_t)}{var(y_{it})} = 1 - \frac{var(u_{it})}{var(y_{it})}$ ……………… (15)

Table 2 presents the contribution of common factor to the volatility of house price growth rate in the second column. The contribution of common factor ranges from 0.293 (Shandong) to 0.875 (Zhejiang). In the case of high-growth regions, the contribution of common factor of Zhejiang is the highest (0.875), and then Beijing (0.849), Jiangsu (0.828), Shanghai (0.807). Note that these regions have both high values of the factor loading and high contribution of common factor to volatility of house prices. In the case of the low-growth regions, the contribution of common factor of Ningxia is the highest (0.713), and then Sichuan (0.684), Guangdong (0.674), Jilin (0.667), and Guizhou (0.612). Whereas, for the rest regions in the low-growth group, the contributions of common factor are relatively low. Note that Guangdong and Sichuan are relatively developed regions with high values of factor loading and high contributions of common factor.

We find that, in general, the contributions of common factor to the volatility of house prices are relatively higher in the regions of high growth group. However, the high (low) value of factor loading does not necessarily mean the high (low) contribution of common factor to the movement of regional house prices. For instance, the values of factor loading of Tianjin, Hainan, and Ningxia are relatively low but the contributions of common factor of these regions are high; the value of factor loading of Gansu is very high but its contribution of common factor is very low.

The result implies that regions with high growth of house prices may be closely connected to or representative of national economy, which is reflected by high values of the factor loading or high contributions of common factor to price volatilities, or both. There are two reasonable interpretations for high values of factor loading coefficients and volatility contributions of common factor in the regions of high growth rates of house prices. First, high growth of house prices of those regions may possibly reflect favorable movement of national factors such as national GDP or interest rates. In this case, price growth may be more likely to reflect national fundamental determinants of house prices. Second, the high price growth of those regions may lead to growth of house prices of other regions and result in national house price boom. In this case, the price boom may reflect by large parts bubble.

There is no concrete evidence in the current context which of the interpretations is more plausible. However, we can indirectly examine the alternative interpretations by excluding Beijing and Shanghai, the most developed large cities in China with top growth rates of house prices and comparing the results with the model of full sample. The results are reported in the last two columns in Table 2. If the growth of house prices of the two cities lead to price boom of other cities, the model may yield different pattern of estimation results. One notable change is found in Hainan: the contribution of common factor of Hainan decreases from 0.656 to 0.355. Note that Hainan is a tourist region with underdeveloped economic level and low per capita income. This implies that the house price boom in Hainan may be driven by the spillover effect of Beijing and Shanghai, implying the high probability of existence of bubble in Hainan. In other regions, however, no substantial difference from the full sample is not found and thus price growth of these regions may be driven by national fundamentals rather than the price growth of the two leading cities.

4.1.2. Factor-loading VAR Analysis: The Effects of Monetary Policy

In the preceding section, the common factor was estimated in the full sample model. The loading coefficients in this context signify the sensitivity of house price growth to the common factor. Higher values indicate a stronger influence of changes in common factors on regional house prices, suggesting a tighter connection between these regions and nationwide factors like monetary policy instruments. Consequently, we hypothesize that national fundamentals, including monetary policy instruments, real output and inflation rate, may impact regional house prices through their effects on these common factors. This section aims to examine the effects of monetary policy on national house price and common factor by using standard VAR model and factor-loading VAR model respectively.

Figure 3 compares the difference between national house price growth rate and common factor over the sample period, where the common factor is estimated from the full sample model showed in Table 2. Even though the trends of national house price growth rate and common factor look similar, they are actually quite different. For instance, during the period 2000:10-2001:07, the growth rate of national house price increases from 4% to 12%, but the common factor just fluctuates without any increase in this period. Another example is the period 2003:08-2004:09. The growth rate of national house price increases with a smaller volatility, whereas the common factor decreases with a larger volatility. During the international financial crisis, especially the period 2008:01-2008:08, the growth rate of national house price decreases with a smaller volatility, but the common factor increases with a larger volatility.

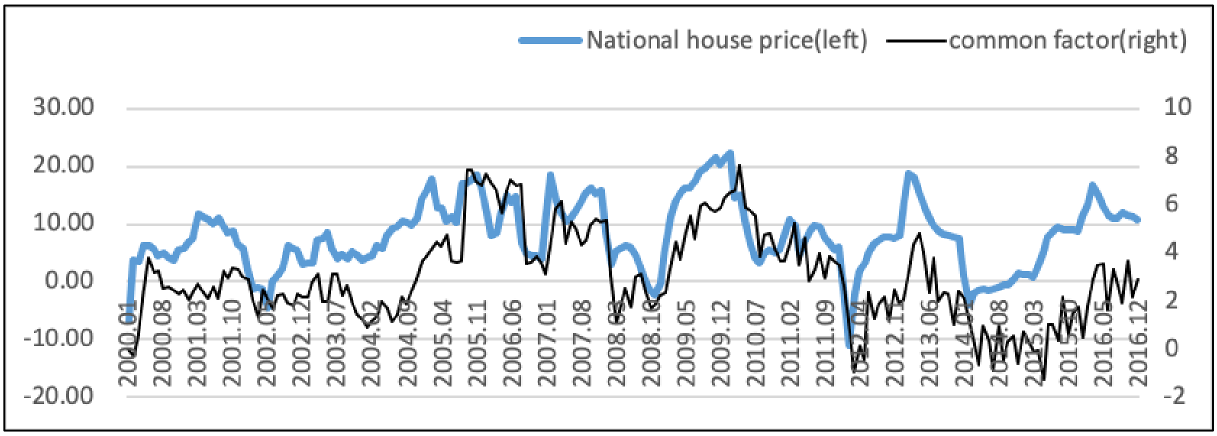
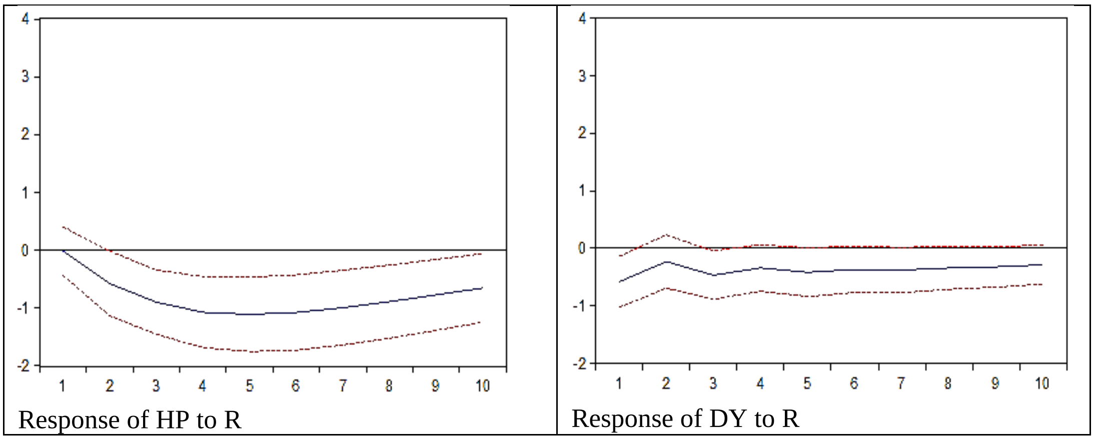


Figure 3: National house price growth rate and common factor

Note: The left vertical axis represents growth rate of national house price (%), the right vertical axis represents common factor and the horizontal axis represents sample period. The figure is made by the authors.

Furthermore, we can also find significant differences between the growth rate of national house price and common factor during the period 2012:04-2012:12 and 2014:01-2015:03. Given the obvious differences between the national house price and common factor, the policy evaluation based on national average of house prices may be misleading form the perspective of regional house prices. In order to verify the hypothesis, we will examine the effect of monetary policy on the both national house price and common factor. We begin by estimating a standard VAR model to estimate the effect of monetary policy on the movement of national house price, followed by a factor-loading VAR model to evaluate the effect of monetary policy on common factor.

According to Bernanke *et al*., (2005), the factor-loading VAR model is much more efficient and practical to estimate the effect of monetary policy by reducing the problem of degree-of-freedom. If we use the standard VAR system to examine the effects of monetary policy on the 30 regions' house prices, the standard VAR (30+3) will lead to biased analysis because of degree-of-freedom problems. Moreover, the effect of monetary policy on common factor reflects the effect of monetary policy on the movement of regional house prices through the factor loading coefficients. We construct the factor-loading VAR model with four endogenous variables: common factor, the growth rate of national industrial production (DY), inflation rate (DP), and monetary policy (proxyed by short-term interest rate, R).



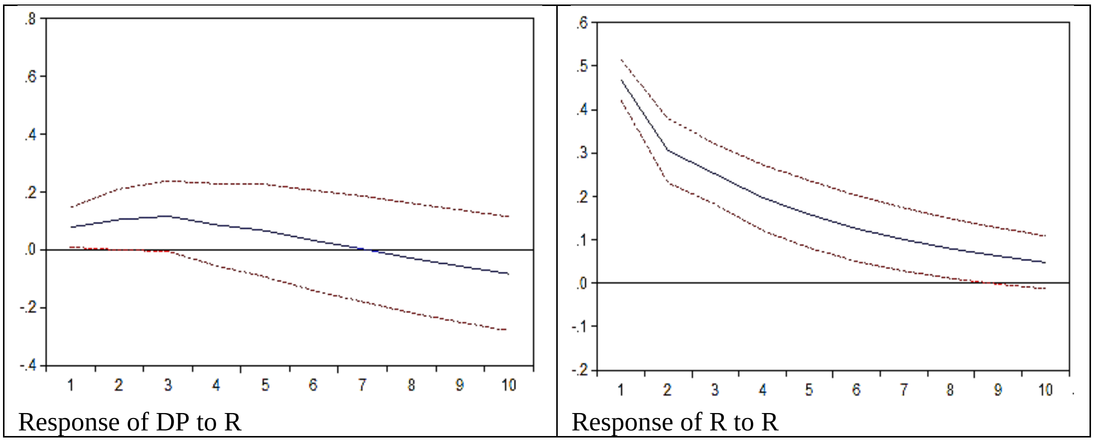


Figure 4: Impulse responses of all variables to one standard error shock to interest rate: Standard VAR analysis

Figure 4 shows the results of impulse response analysis generated from the standard VAR system, which consists of national house price growth rate (HP), industrial production growth rate (DY), inflation rate (DP) and interest rate(R). According to the figure, the impulse response of HP to the positive shock to interest rate is negative, and it is statistically significant in the 90 percent confidence intervals. However, this result does not mean that the monetary policy can affect the regional house prices in the same way.

Figure 5 shows the impulse response analysis generated from the factor-loading VAR model. Comparing with the results of Figure 4, we find that the impulse response of the common factor to the positive shock to interest rate is much stronger and more persistent. The result indicates that monetary policy can affect significantly on the movement of regional house prices through the factor loading coefficients. Our analysis suggests that policymakers can design tight monetary policies to curb the overheating house prices in China.

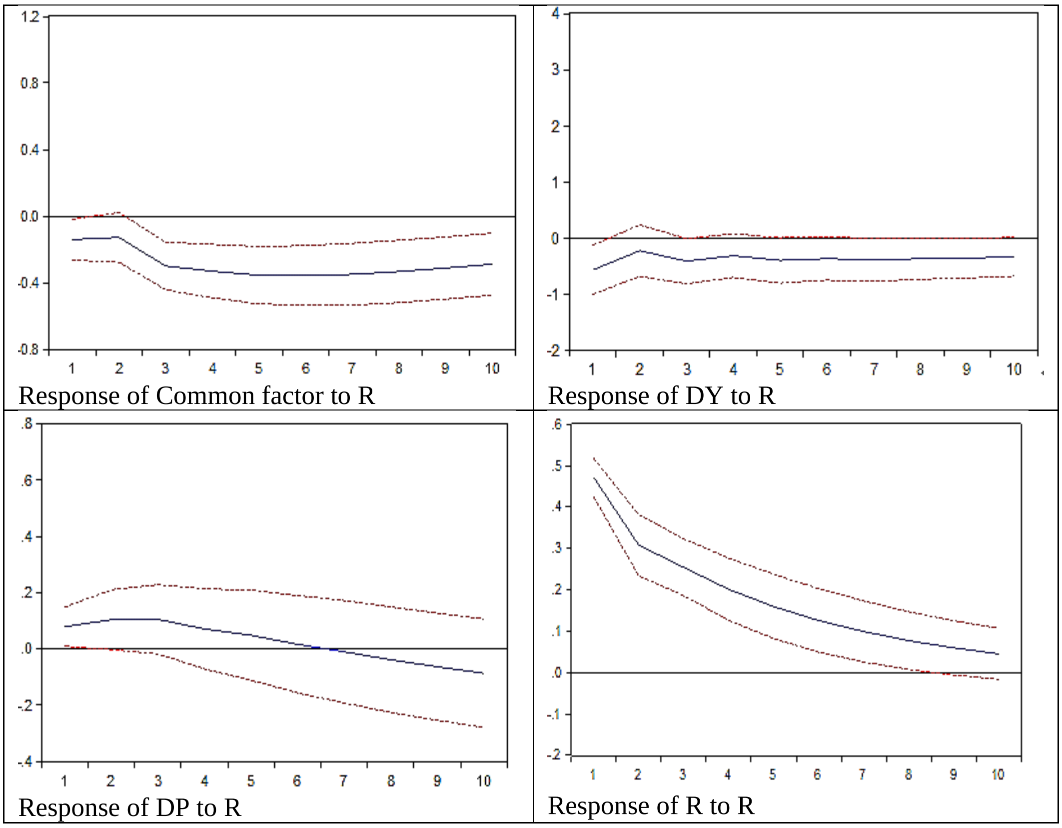


Figure 5: Impulse response of all variables to one standard error shock to interest rate: Factor-loading VAR analysis

Table 3: Overall convergence of regional house prices and regional GDP

	House price		GDP	
	$\hat{\gamma}$	t-statistic	$\hat{\gamma}$	t-statistic
1979-2016	-	-	-0.065	-1.365
1999-2016	-0.474	-3.980	-0.407	-8.935

4.2. Log-t Convergence Test

In this section, we use *log t* convergence test to test the existence of overall convergence and club convergence in regional house prices and regional GDP. A comparison can, to some degree, address the issue of relative importance of common factors vis-à-vis regional factors.

4.2.1. Overall Convergence Test

Table 3 reports the estimation results of the convergence of regional house prices and regional GDP. If $t_{\hat{\gamma}}$<-1.65, the null hypothesis, existence of overall convergence ($\gamma = 0$), is significantly rejected at the significance level of 5%. For regional house prices, the values of $\hat{\gamma}$ and t-statistic are -0.474 and -3.980 respectively, indicating a rejection of overall convergence.

For regional GDP, we perform the convergence test for two periods: 1979-2016 and 1999-2016. In the first period, the values of $\hat{\gamma}$ and t-statistic are -0.049 and -1.026 respectively, indicating the null hypothesis cannot be rejected at the significance level of 5%. On the contrary, in the second period, the values of $\hat{\gamma}$ and t-statistic are -0.407 and -8.935 respectively, indicating that the null hypothesis of existence of overall convergence in regional GDP is significantly rejected. The results show evidence of existence of overall convergence among regional GDP in the long period, but the overall convergence disappears in the recent period, implying the rising problem of cross-region inequality in GDP in these decades. This is consistent with the view of many related studies (e.g. Fujita *et al*., 2001; Yao and Zhang, 2001; Benjamin *et al*., 2005, etc.).

4.2.2. Club Convergence Test

We have showed the evidence of absence of overall convergence in both regional house prices and regional GDP in the period 1999~2016 Does this mean divergence in both regional house prices and regional GDP? Do there exist club convergence in regional house prices and regional GDP? If so, are the club members of regional house prices consistent with those of regional GDP? In order to answer these questions, we perform the club convergence tests for regional house prices and regional GDP over the period 1999~2016. The results are reported in Table 4 Panel A and B, respectively.

In the case of regional house prices, our club convergence tests show three clubs. The values of the convergence parameter $\hat{\gamma}$ of Club 1, 2 and 3 are 0.144, 0.874 and 0.146 respectively. The proportions of regions of Club 1, Club 2 and Club 3 are 10 % (3 regions), 16.7% (5 regions) and 73.3% (22 regions) respectively. Club 1 consists of Beijing and Shanghai, the two most developed regions with highest house prices, which are high-growth regions. Club 2 consists of 10 regions with higher house price levels than Club 3. These regions except Guangdong and Sichuan are also high-growth regions. In addition, excluding a few regions [12], most of the members of Club 1 and 2 are regions in which house prices are affected significantly by monetary policy. Club 3 consists of the remaining regions with low house prices. Our empirical results imply that the club convergence of regional house price is generally consistent with the results from a short-term perspective.

Table 4: Club convergence of regional house price and regional GDP

Panel A House Price				
	$\hat{\gamma}$	**t-statistic**	**Club members (No. of members)**	**Proportion**
Club 1	0.144	(1.375)	Beijing, Shanghai (2)	10.0%
Club 2	0.874	(2.761)	Tianjin, Zhejiang, Jiangsu, Fujian, Hebei, Hainan, Jiangxi, Chongqing, Guangdong, Sichuan (10)	16.7%
Club 3	0.146	(0.924)	Neimenggu, Anhui, Henan, Hubei, Shaanxi, Gansu, Liaoning, Jilin, Heilongjiang, Shandong, Shanxi, Hunan, Guangxi, Guizhou, Yunnan, Qinghai, Ningxia, Xinjiang (18)	73.3%
Panel B GDP				
	$\hat{\gamma}$	t-statistic	Club members (No. of members)	Proportion
Club 1	0.153	(1.982)	Tianjin, Neimenggu, Liaoning, Shanghai, Jiangsu, Fujian, Shandong, Chongqing (8)	26.7%
Club 2	0.124	(1.449)	Beijing, Jilin, Heilongjiang, Zhejiang, Anhui, Henan, Hunan, Hubei, Guangdong, Sichuan, Shaanxi (11)	36.6%
Club 3	0.017	(0.261)	Hebei, Shanxi, Jiangxi, Guangxi, Hainan, Qinghai, Ningxia, Xinjiang (8)	26.7%
Club 4	0.065	(0.770)	Guizhou, Yunnan, Gansu (3)	10.0%

Note: The bold regions are high growth regions while the others are low growth regions.

[12] Such as Hainan, Jiangxi, Hebei.

In case of regional GDP, our club convergence tests show four clubs. The values of $\hat{\gamma}$ are 0.153, 0.124, 0.017 and 0.065, respectively. The proportions of regions are 26.7% (8 regions), 36.6% (11 regions), 26.7% (8 regions) and 10% (3 regions) respectively. Lower $\hat{\gamma}$ of regional GDP indicates that the club convergence are much stronger and faster in regional house prices, relative to regional GDP. In order to see whether the convergence of regional house prices is driven by regional GDP, the club members of regional house prices are compared with those of regional GDP. We find significant differences. Hainan and Jiangxi are identified as Club 2 members with high house prices, but Club 3 members with low GDP levels. Beijing and Shanghai are identified as Club 1 members with the highest house prices, but in different clubs of regional GDP. Therefore, our empirical results indicate that the house price boom, especially in main regions, may not be mainly driven by regional fundamental factors such as regional GDP.

5. DISCUSSION

Motivated by the heterogeneity of house price growth rates across regions in China, this paper aims to investigate the movement of regional house prices in China in a short-term and long-term perspective. Firstly, this paper employs a dynamic factor model to identify common factors and regional specific factors affecting house prices. Additionally, we investigate the impact of monetary policy on house price movements using factor-loading VAR models, analyzing its heterogeneity on national house prices and common factors. Finally, we conduct *log t* convergence tests to explore overall and club convergence in regional house prices and GDP both regional house prices and regional GDP.

Our research reveals that house prices, particularly in high-growth regions, are predominantly influenced by common factors, even though regional factors are also sizeable enough to attract attention. This is consistent with the Weng and Gong (2016) paper, which find that the comovement of house prices is significantly affected by population, income, and national macroeconomic situation. However, our finding is inconsistent with previous research of Huang *et al*., (2015) and Zhang *et al*., (2017). Huang *et al*., (2015) demonstrate city-specific factors account for a large proportion of the variations of house prices in 2005-2014 China house market and Zhang *et al*., (2017) observe the ripple effect caused by North China and East China as well as the regions with higher economic development level.

Our research findings report that monetary shocks can affect significantly both national house price and common factor, but with more prolonged and stronger impacts on common factor. This study stands as one of the rare endeavors to scrutinize the heterogeneity of monetary policy effects on national house prices and common factors in China. The disparities in these effects underscore that relying solely on a national proxy like national house prices for policy formulation and evaluation could lead to misleading conclusions. Our research finding is inconsistent with existing literature such as Xu and Chen (2012) that examine the impact of key monetary policy variables, including long-term benchmark bank loan rate, money supply growth, and mortgage credit policy indicator, on the real estate price growth dynamics in China. By using national average house price, they find that Chinese monetary policy actions are the key driving forces behind the change of real estate price growth in China.

Our analysis shows little evidence of overall convergence in regional house prices, but strong evidence in favor of club convergence, consistent with Meng *et al*., (2015) and Rui *et al*., (2015). In contrast to prior studies, our research reveals a distinctive pattern: the composition of convergence clubs in house prices markedly differs from those in regional real output. This suggests that regional housing market convergence is not primarily driven by regional fundamentals, such as regional real output.

6. Implications

6.1 Theoretical implications

Our study makes a pioneering contribution to the field by meticulously examining the underlying drivers of regional house price movements in China, which was ignored by previous scholars in the area of house market. While earlier literature often relied on simplistic low-dimensional models such as traditional VAR models with a handful of variables like real GDP, interest rates, CPI, and national average house prices, our approach utilized a sophisticated dynamic factor model. This method allowed us to delve into the complexities of high-dimensional data, enabling the identification of both common factors and region-specific determinants shaping house price dynamics. Contrary to established beliefs, our empirical analysis challenges the prevailing assumption that specific macroeconomic or regional factors singularly fuel house price booms. Instead, our findings underscore the pivotal role played by common factors.

Moreover, we advanced the convergence theory framework by incorporating both overall and club convergence paradigms into the realm of regional house prices and regional fundamentals. Our rigorous examination revealed the absence of overall convergence while confirming the presence of club convergence in both regional house prices and real GDP in China. Crucially, the distinctive composition of these convergence clubs between house prices and regional real GDP suggests that regional house market dynamics are mainly influenced by common factor instead of regional fundamental factor.

6.2 Practical implications

The study highlights the necessity for policymakers to craft nuanced monetary policies, especially considering the varying growth rates of house prices across regions in China, particularly in high-growth areas. The loading coefficients, representing the sensitivity of house price growth to common factors, indicate the degree to which changes in these factors influence regional house prices. Higher values signify stronger connections between regional house prices and national factors like monetary policy instruments, emphasizing the significance of these relationships, particularly in regions experiencing rapid growth.

Our research underscores that regional house prices are predominantly influenced by common factors, with high-growth regions exhibiting a notably stronger impact. Utilizing a factor-loading VAR model, we compared the effects of monetary policy on both national house prices and common factors. The disparities observed in these effects emphasize the limitations of relying solely on national proxies, such as national house prices, for policy formulation and assessment. The empirical result provides valuable insights for policymakers, encouraging a more targeted and region-specific approach in addressing the complexities of China's housing market.

7. LIMITATIONS

Our study exhibits certain limitations. Firstly, the relatively limited sample size comprises monthly panel data from 30 regions (province level) in China over an extended period. However, within specific provinces, house price growth rates may vary significantly among different cities, researchers should broaden sample data with a larger panel dataset encompassing cities or counties.

Secondly, although significant factor loading coefficients are presented in tables, the study does not provide visual representations of response functions illustrating the effects of monetary shocks on house prices across the 30 regions. Future research employing alternative methodologies, such as Factor-augment VAR systems, could offer valuable insights into the heterogeneous effects of monetary policy on regional house price dynamics.

Finally, our study exclusively focuses on the effects of short-term interest rate shocks on national house price and common factor. To comprehensively understand the influence of monetary policy, researchers should expand their investigations to include other monetary policy instruments, such as long-term interest rates, M1, and M2, broadening the scope of analysis.

8. CONCLUSION

Motivated by the heterogeneity of house price growth rates across regions, this paper investigates the movement of regional house prices in China from a short- and long- term perspective. Our research reveals that house prices, particularly in high-growth regions, are predominantly influenced by common factors, even though regional factors are also sizeable enough to attract attention. Based on the results, impulse response function analysis reports that monetary shocks can affect significantly both national house price and common factor, but with more prolonged and stronger impacts on common factor. Furthermore, our analysis shows little evidence of existence of overall convergence in regional house price, but strong evidence in favor of club convergence. The composition of convergence clubs in house prices markedly differs from those in regional real output, which suggests that regional housing market convergence is not primarily driven by regional fundamentals, such as regional real output. The study highlights the necessity for policymakers to craft nuanced monetary policies, especially considering the varying growth rates of house prices across regions in China, particularly in high-growth areas.

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