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Can bank credit withstand falling house price in China?

Chi-Wei Su [a,*], Xu-Yu Cai [a], Meng Qin [b], Ran Tao [c], Muhammad Umar [a]

[a] School of Economics, Qingdao University, China
[b] Graduate Academy, Party School of the Central Committee of the Communist Party of China (National Academy of Governance), China
[c] Qingdao Municipal Center for Disease Control & Prevention, China

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ABSTRACT

This paper examines whether the falling house price causes credit risk or not in China. We note that bidirectional causal relationships exist in several sub-periods using sub-sample rolling window test. Our analysis confirms the option-based model (Foster & Van Order, 1984) that proves the falling house price leads to more defaults of mortgage and increasing credit risk. Meanwhile, the rise in credit risk is likely to be accompanied by the increasing house price. Rising house price has no impact on credit risk. We find banks' credit expansion may be irrational which leads to the accumulation of credit risk. The tight credit policies and high loan interest rates stimulate the house price to fall. In addition, based on the analysis of the previous periods, we do not think that the credit risk will explode systematically in China with the current situation of mortgage growth slowing down. However, due to the pivotal role of real estate credit in loan structure of banks in China, we still need to be alert to the potential accumulation credit risk caused by the default of individuals and enterprises. It is essential for banks to strengthen the examination of personal credit certificates to prevent speculative loans. Regulators should take into account the impact on bank credit when they formulate policies to control the house price.

1. Introduction

This study aims to explore the causality between house price and credit risk in China. From conventional perspectives, the rise in house price leads to the accumulation of credit risk (Bian et al., 2018; Chaibi & Ftiti, 2015). When the house bubble bursts, banks suffer losses due to the explosion of credit risk, which can threaten the entire financial system (Bernanke & Gertler, 1990; Kiyotaki & Moore, 1997). Prior to the subprime crisis in the United States, studies tend to focus on loans to house buyers and real estate enterprises (Miller & Peng, 2006). Black et al. (1996) hold that when the market value of the house declines, the repayment willingness of the borrower decreases, which leads to an increase in credit risk. Kau et al. (1994) also examine this relationship by regarding mortgage default as selling options and conclude that falling house price leads to an increase in mortgage defaults. Besides housing mortgage loans, defaults of loans to real estate enterprise is also an important intermediary connecting the fluctuation of house price with credit risk (Patel & Vlamis, 2006). After the subprime crisis, the role of asset securitization and credit derivatives in the relationship between house price and credit risk causes much attention (Demyanyk and Hemert, 2011; Mian and Sufi, 2009). The mechanism of the interaction between house price and credit risk varies with actual economic situations. Moreover, it is also emphasized that this interaction may vary across countries and regions (Agnello & Schuknecht, 2011; Coskun et al., 2020; Tajik et al., 2015). Stable house price and low credit risk play an important role in economic stability and preventing financial crisis. The higher credit scale in real estate markets leads to the greater

* Corresponding author. School of Economics, Qingdao University, 308, Ningxa Rd., Qingdao, Shandong, China.
E-mail addresses: cwsu7137@gmail.com (C.-W. Su), umar@qdu.edu.cn (M. Umar).

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dependence of banks on the real estate boom (Himmelberg et al., 2005). As well as creating and exacerbating the house price bubble, credit risk poses serious challenges to the entire financial system (Dell'Ariccia et al., 2012).

The relationship between house price and credit risk in China attracts extensive attention in recent years. Although the Chinese regulators implement the limited purchasing order and differentiated credit constraints, house price is still rising (Chen et al., 2013). At the beginning of 2017, China Residential House Price Index in 100 Cities (HPI-100) increases by 78.6% compared to December 2010. This rise in house prices is attributed to the phenomenon of real estate excessive speculation and the government monopolizing the supply of land in China (Wen & Goodman, 2013). The excessive raising of house price will not only have a crowding-out effect on consumption (Dong et al., 2017) but most importantly lead to the dramatical expansion of bank credit (Shen et al., 2016). Since the monetization of housing distribution is implemented in 1999, real estate-related loans have expanded sharply (Huang et al., 2015). On the one hand, although the real estate financing channels show the trend of diversification, the funds provided by equity and bond financing are not sufficient to reach the demand of the real estate industry. The real estate financing market is still dominated by bank credit (Chan et al., 2016). On the other hand, there is a mismatch between mandatory and market-oriented loan allocation mechanism in the housing provident funds (Tang & Coulson, 2017). The loan balance of individual housing provident funds accounts for less than 20% of individual housing loans, while the housing mortgages account for a large proportion. Commercial banks are the main credit providers of Chinese real estate industry. In 2016, more than 60% of the incremental individual loans made by commercial banks comes from housing mortgage loans, and the loan to real estate enterprises contributes more than 30% to total industries lending. Moreover, the bank credit has shown the trend of centralization, especially in the Eastern coastal areas of China, which stimulates the generation of price bubble (Zhou et al., 2017). However, the accumulation and inefficient disposal of non-performing loans gradually become the hidden danger of credit risk (Zhu et al., 2016). The Ministry of Finance of the People's Republic of China restrains the rising house price through administrative interventions such as purchase limitation. There is an adverse impact on profitability and external financing for real estate enterprises (Sun et al., 2017). As a result, the default rate of enterprise loans increases because of the inferior capital liquidity and refinancing capacity. In addition, falling house price may lead to rational defaults on housing mortgages (Fang et al., 2016). The scale of non-performing loans in the real estate industry increased rapidly and the annual growth rate reaches 73% in 2015. Credit quality in real estate-related loans deteriorates in recent years (Fenech et al., 2014), with nearly 50% of incremental non-performing loans tied to real estate industry in 2017. China Banking Regulatory Commission (CBRC) requires commercial banks to carry out stress tests on real estate-related loans and conduct dynamic monitoring analysis for controlling credit risk. However, there is a large amount of capital demand of the real estate industry which depends on credit loans from commercial banks (Chen & Wen, 2017). The explosion of credit risk still jeopardizes the operating of commercial banks. Therefore, it is significant to study house price and credit risk, with special attention paid to investigating whether falling house price causes credit defaults and threaten the banks in China.

The contributions of this paper to the existing literature are as follows. We find that changes in credit policies and loan interest rates have an impact on house prices. Credit risk is caused by the decrease of capital liquidity of real estate enterprises and the rational default of mortgage loans due to the falling collateral value. Hence, the authorities should be prudent about the impact on bank credit quality when formulating policies to control house price. We indicate that speculative purchases threaten not only the stability of house price but also the credit risk management of banks. We also hold that other than the previous periods in which interaction exists, the credit risk is not likely to erupt systematically in a short term under the conditions of moderate real estate market and slow mortgage loan growth. But we should be vigilant in credit risk management in case of frequent defaults. Additionally, with the consideration of structural changes in series, we note that the dynamic link between house price and credit risk shows the instability between different sub-samples using a bootstrap Granger full-sample causality test and sub-sample rolling window estimation (Balcilar et al., 2010; Su et al., 2019, 2020). We use quarterly data which covers the period from 2004:Q1 to 2018:Q2 to investigate this time-varying bidirectional relationship between house price and credit risk. The empirical results show that house price has negative influences on credit risk while credit risk is positively affected by house price. Furthermore, the mutual influence between house price and credit risk provides insights to the authorities and investors. The examination of personal credit certificates should be strengthened to prevent speculative loans. It is significant for the banking sector to prevent the excessive expansion of credit and monitor the quality of credit loans in order to control the credit risk effectively.

The remaining parts are composed as listed below: The literature review and the option-based model of house price and credit risk are presented in Section 2 and Section 3 respectively. Section 4 outlines the bootstrap rolling window approach. Section 5 and 6 discuss the corresponding data and empirical analysis. Section 7 shows the conclusion of this paper.

2. Literature review

There is a consensus that falling house price induces the increase credit risk of banks, but the results show discrepancy by focusing on different transmissions and economic environments. Herring and Wachter (1999) indicate that falling house prices will reduce banks' capital by reducing the value of their own property assets and the value of their mortgages, which could lead to a rise in credit risk. Titman and Torous (2007) find that different types of mortgage (term, floating rate or fixed rate) have great differences in the impact on the credit risk. Adjustable-rate mortgages are more likely to default when house price and inflation are uncertain (Campbell & Cocco, 2003). Other studies hold that excessive credit expansion is also an important intermediary. Holt (2009) argues that low-interest rates and slack credit standards contributed to a more extreme house price bubble and expansion of low-quality mortgage, leading to more severe credit risks. The credit expansion of real estate enterprises also have the same effect, but larger enterprises are less prone to default than smaller enterprises and smaller banks are confronted with higher credit risks than bigger banks (Hancock & Wilcox, 1998; Kashyap & Stein, 2000). The reason is that small enterprises tend to deal more with smaller banks and are more vulnerable to falling house prices (Hancock & Wilcox, 1994).

Transmission pathways may vary in different situations. By analyzing the bubble characteristics of house price during the subprime crisis, Phillips and Yu (2011) find that the dateline of the house price bubble bursting coincides with the increase of loan defaults, which indicates credit risk outbreaks. The quality of loans deteriorated before the crisis is masked by high house price appreciation (Bailey et al., 2019; Demyanyk & Van Hemert, 2009). When the default rate of mortgage increases, mortgage-backed securities (MBS) investors suffer huge losses, leading to the collapse of the financial system (Mayer et al., 2009). These points of view are also supported by Dell'Ariccia et al. (2012) and Purnanandam (2010), which indicate that the relationship between house price and credit risk plays a significant role in a stable financial system. Igan et al. (2011) hold that there are lead-lag relationships among house price, credit risk and business cycles varying across countries. Moreover, the real estate industry has procyclicality which means the performance of real estate enterprises changes in the same direction as the economic cycle (Bertay et al., 2012; Bhat et al., 2019). The credit risk resulting from falling house price can be amplified when the economy is in depression (Jeske et al., 2013).

Since Gertler and Bernanke (1989) propose that credit scales can magnify real estate market fluctuations, the feedback mechanism between house price and credit risk has been proved (Almeida et al., 2006). Kiyotaki and Moore (1997) indicate that the dynamic interaction between credit and house price is a powerful transmission mechanism that expands and spread the credit default to other sectors, causing credit risk. Shin (2008) also proves that once the house price bubble bursts, the value of net assets of both lenders and the bank will shrink credit dramatically. The bank will suffer losses due to default, which leads to a further decline in the house price. Aoki et al. (2004) hold that the feedback mechanism between them amplifies the economic fluctuations because of the procyclicality of house prices and bank credit. Similar conclusions are proposed in many studies (Iacoviello, 2005; Kannan et al., 2012).

The impact of credit risk on house price is also proved by existing literature. Favara and Imbs (2015) indicate that when credit risk is expected to rise, banks will cut the supply of credit, which result in falling house price. The pessimism of consumer and investor raises the credit risk of housing mortgages, depressing future house prices (Chauvet et al., 2016). Anundsen et al. (2016) argue that banks' irrational credit expansion is the cause of the accumulation of credit risks, and this expansion leads to the rise in house prices. This phenomenon causes banks to increase mortgage lending and reduce commercial lending. Banks' credit risk can be magnified by this crowding-out effect (Chakraborty et al., 2018; Killins, 2020).

Ren et al. (2012) hold that there is no evidence to support the existence of bubbles in the house price and accumulated credit risk in China. Zhang et al. (2018) also indicate that credit risk is barely affected by distressed house price in China. However, Zhi et al. (2019) argue that the house price in China's first-tier cities is in a bubble and the hidden credit risks exist in banks. When the market value of the house is less than the present value of the remaining balance of the mortgage, borrowers have a motivation to default (Deng & Liu, 2009). Wan (2018) also reveals that the house price has a significant negative impact on credit risk in China, and attributes this result to raising vacant houses, decreasing housing investment and profit of real estate enterprise.

Previous literature neglects the time-varying Granger causality between house price and credit risk, which cannot identify whether the impact at different times is negative or positive (Su et al., 2020a, 2020b). In addition, the exogenous factors that lead to the fluctuation of house price may be different in some periods. The main transmission process which conducts the relationship between house price and credit risk may be changed by the economic environment. In order to address these gaps, we propose the bootstrap sub-sample rolling window Granger causality test to describe the relationship and try to explain it based on the actual situation in China.

2.1. Option-based model of credit risk

Option-based model is proposed by Foster and Van Order (1984). When the house price is less than the price of the loan, the rational borrower (Household or enterprise) can reduce the repayment cost by default. Let the house price at time t be $H(t)$, the market value of the borrower's outstanding loan be $M(t)$, and the transaction cost of buying a house at market price after default at time t is $\beta H(t)$ where $0 < \beta < 1$.

We assume the loan is complete amortizing, the house price is H_0 when the loan contract is signed. The repayment term is T years and the proportion of loan is γ, the interest rate is $i(1)$ in the first year. The payment of year T is determined by the interest rate $i(T)$. Hence, the outstanding $B(t)$ at the end of year t is:

$$B(t) = H_0\gamma - \sum_{j=1}^{t} E(j) = H_0\gamma - \sum_{j=1}^{t} \frac{A(t)}{[1+i(1)]^{T-1} - 1}, \tag{1}$$

where $A(t)$ is the repayment at time t and $E(j)$ is the outstanding principal of loans at the end of year j. Default is regarded as a European put option embedded in loans. According to the Black-Scholes option pricing model (Black & Scholes, 1973), let the motion of house price be:

$$\frac{dH}{H} = \mu(t)dt + \sigma(t)dz, \tag{2}$$

where $dz = \varepsilon\sqrt{t}$. The value of this option is:

$$V(H,t) = B(t)e^{-rt}N(-d_2) - (1+\beta)H(t)N(-d_1), \tag{3}$$

where $d_1 = \frac{\ln(1+\beta) + \ln H(t) - \ln B(t) + \left(r + \frac{1}{2}\sigma^2(t)\right)t}{\sigma(t)\sqrt{t}}$ and $d_2 = d_1 - \sigma(t)\sqrt{t}$.

The banks may face credit risk which is measured by the probability of default $N(-d_2)$. At the end of t, the borrower chooses to pay the outstanding loan or default. β is the proportion of liquidated damages and transaction costs to the house price. Assuming the expected growth rate of house price $\mu(t)$ and the volatility $\sigma(t)$ are constant, the probability of default P can be calculated as:

$$\begin{aligned} &P[\ln(1+\beta)+\ln H(t)<\ln B(t)] \\ &= P\left[\ln(1+\beta)+\ln H_0+\left(\mu-\frac{1}{2}\sigma^2\right)t+\sigma\sqrt{t}z<\ln B(t)\right] \\ &= N\left(-d_2^*\right) \end{aligned} \tag{4}$$

where $d_2^* = \frac{\ln(1+\beta)+\ln H_0+\left(\mu-\frac{1}{2}\sigma^2\right)t-\ln B(t)}{\sigma\sqrt{t}}$.

Adverse external shocks lead to falling house price. Household and real estate enterprise choose to default when the value of outstanding loans exceeds the house price. When house price is expected to fall faster ($\mu<0$), the probability of default on loans P will be higher, which indicates that banks face more credit risk.

3. Methodology

3.1. Bootstrap full-sample granger causality test

Toda and Phillips (1993) point out that only when the sample series are stationary do the test statistics follow the standard asymptotic distribution, which may distort the test results. Shukur and Mantalos (1998) propose the residual-based bootstrap (*RB*) method to solve this problem and prove that this method can improve the causality test. In addition, the *RB* method is more reliable for standard asymptotic tests and for power and size properties in small sample corrected the likelihood ratio (*LR*) tests (Shukur & Mantalos, 2000). Therefore, the *RB*-based modified-*LR* statistic is adopted to analyze the links between house price and credit risk in this paper. Considering the correlation between these two variables, a vector autoregressive (VAR) model is constructed:

$$y_t = \varphi_0 + \varphi_1 y_{t-1} + \cdots\cdots + \varphi_p y_{t-p} + \varepsilon_t \quad t = 1,\ 2, \cdots\cdots,\ T \tag{5}$$

where $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t})'$ is the white noise process. Equation (5) can be expressed as follows:

$$\begin{pmatrix} CR_{1t} \\ HP_{2t} \end{pmatrix} = \begin{pmatrix} \varphi_{10} \\ \varphi_{20} \end{pmatrix} + \begin{pmatrix} \varphi_{11}(L) & \varphi_{12}(L) \\ \varphi_{21}(L) & \varphi_{22}(L) \end{pmatrix} \begin{pmatrix} CR_{1t} \\ HP_{2t} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix}, \tag{6}$$

where the lag operator L can be expressed as $x_{t-k} = L^k x_t$, $\varphi_{ij}(L) = \sum_{k=1}^{p+1} \varphi_{ij,k} L^k$, $i,\ j = 1,\ 2$. According to Equation (6), the null hypothesis that the credit risk (CR) does not Granger cause the house price (HP) is $\varphi_{12,\ k} = 0$. Similarly, $\varphi_{21,\ k} = 0$ represents the other null hypothesis that the HP does not Granger cause the CR, where $k = 1,\ 2,\ \cdots\cdots\ ,\ p$. It is indicated that the HP is the Granger cause of the CR and vice versa if these assumptions are rejected.

3.2. Parameter stability test

It is proved that the parameters of the VAR model will show instability if the full-sample data has structural changes, which leads to incorrect conclusions (Balcilar & Ozdemir, 2013; Su et al., 2020a, 2020b; (Su et al., 2020c)). Therefore, the test of parameter stability is necessary in order to surmount the nonconstancy of the parameter. The *Exp-F*, *Mean-F*, and *Sup-F* tests (Andrews, 1993; Andrews & Ploberger, 1994) and L_c test (Hansen, 1992; Nyblom, 1989) are applied to verify the stability of parameters. In order to increase accuracy, the critical values and p-values of the parameter stability test are obtained by means of using an asymptotic distribution which is constructed through Monte Carlo simulations. Meanwhile, the sample data within the interval (0.15, 0.85) are selected to calculate the test statistics.

3.3. Bootstrap sub-sample rolling-window granger causality test

When structural changes exist in the whole time series, although the sample splitting or dummy variables method can be used to solve the problem, the bias will generate, which affects the Granger causality test results (Su et al., 2019, 2020). Balcilar (2010) proposes the test which divides the whole series into small samples with the fixed window width l. The length of the subsample sequence is $t = \tau - l + 1,\ \tau - l, \cdots,\ T$, where$\tau = l,\ l+1, \cdots,\ T$. The *RB*-based modified-*LR* test is applied to examine the causal relationship between variables in sub-samples. The average of a large number of estimations $N_b^{-1}\sum_{k=1}^{p} \widehat{\varphi}^*_{21,\ k}$ and $N_b^{-1}\sum_{k=1}^{p} \widehat{\varphi}^*_{12,\ k}$ are defined as the impact of HP on CR and the impact of CR to HP respectively. N_b represents the number of bootstrap repetitions, $\widehat{\varphi}^*_{21,k}$ and $\widehat{\varphi}^*_{12,k}$ are bootstrap estimates from the VAR models. Meanwhile, Balcilar (2010) points out that the lower limit and upper limit of the confidence interval are calculated by 0.05 and 0.95 quantiles of $\widehat{\varphi}^*_{21,k}$.

It should be pointed out that the higher rolling window size makes estimates more accurate, but at the same time reduce the

representativeness when heterogeneity exists and increase the standard error of estimations. On the contrary, the lower rolling window size increases the representativeness of sub-samples and reduces the standard error of estimation, but it makes estimations less accurate. Pesaran and Timmermann (2005) illustrate that, in order to find the trade-off between exactitude and typicality, the window size should be more than 20. Compared to the traditional full-sample Granger causality test, the sub-sample rolling window Granger causality test provides a special insight about the relationship between this two variables. This method not only permits the causal relationship between variables to change over time but also can observe the instability caused by the existence of structural changes between different sub-samples (Su et al., 2020a, 2020b). Based on the excellent features of sub-sample rolling window Granger causality test, we indicate that this method is suitable to describe more accurately the time-varying relationship between house price and credit risk in China.

4. Data

Considering quarterly data from 2004:Q1 to 2018:Q2, we aim to examine the interaction of house price and credit risk. Since 2004, CBRC has conducted comprehensive monitoring and assessing on the non-performing loans in non-credit assets of commercial banks, but the balance is still rising. Meanwhile, the authorities begin to introduce regulation policies to intervene in house price from 2004, which may cause the level of house price to deviate from the market condition. We use National Real Estate Prosperity Index (NREPI)[1] (Xu & Wang, 2010) and the non-performing loan balance of joint-stock commercial banks[2] (Avery & Berger, 1991) to measure the house price and the credit risk in China respectively. The higher quantified score of NREPI means more prosperous real estate market, and vice versa (Zhang et al., 2015). On the other hand, non-performing loan balance represents the losses that banks suffer, which is regarded as an indicator to measure credit risk (Tajik et al., 2015). Original time series are converted by taking natural logarithms to avert dimensional differences and potential heteroscedasticity.

The balance of non-performing loans decreases during 2004:Q1 to 2011:Q2, but then begins to rise dramatically after this period. The balance reaches 398 billion yuan at the beginning of 2018 compared with 56.3 billion yuan at the end of 2011, which means credit risk is increasing from 2011 to 2018. Meanwhile, with the increasing non-performing loans in 2013, 2014:Q4-2015:Q2, NREPI tends to decrease during these periods. It is also indicated that when non-performing loans increases in 2016 and 2017, the NREPI rises simultaneously reaching 101.7 at the beginning of 2018.

5. Empirical results

We construct bivariate VAR models of HP and CR to investigate the full-sample causal link. The optimal lag length of HP and CR is 3 according to Schwarz Information Criteria (SIC). Table 1 describes the results in terms of *RB*-based modified-*LR* tests. It is illustrated that significant Granger causality does not exist between HP and CR, which is contradictory with existing literature (Castro, 2013).

If the whole time series have the characteristics of structural changes, parameters of VAR model will change with time, which leads that the full-sample Granger causality test becomes unreliable (Zeileis et al., 2005). The parameter stability test results are shown as follows (see Table 2).

In the first row, *Sup-F* test asserts that there are conspicuous shifts in HP and CR. Similarly, the *Mean-F* and *Exp-F* tests mean equations from the HP and CR may evolve gradually with time at the 1% significance level in the second and third row. Meanwhile, all three tests indicate that the structural changes exist in the VAR system. The L_c statistics test examines whether parameters obey the random walk process or not. In terms of the fourth row, the L_c test shows parameter nonconstancy in the VAR system.

Based on previous analysis, the full-sample Granger causality test has been shown to be unreliable because of the existence of the structural changes. We attempt to take rolling windows estimation for examining the causality in order to overcome the structural changes in series. According to Pesaran and Timmermann (2005), the rolling-window size is selected for 24 quarters[3] to balance the exactitude and typicality in this paper. The *p*-values of *LR*-statistics are calculated by using the VAR models in Equation (6).

Figs. 1 and 2 shows the *p*-values and the coefficients for the impact of HP on CR respectively. The horizontal line represents a 10% significance level. If the *p*-value is less than 0.1, which indicates that the alternative hypothesis should be accepted. That is, HP does Granger cause CR. There are two sub-sample periods that the null hypothesis can be rejected, including 2013:Q1-2013:Q3 and 2014:Q4-2015:Q2. According to Fig. 2, we can find that HP has a negative impact on CR in these periods.

After the promulgation of ''Ten Points by the State Council'' of China in 2010, the authorities implement more strict measures to differentiated housing mortgage loans. In 2013, the Ministry of Finance raises the down-payment ratios and mortgage interest rates, which effectively suppress the demand for house purchase and play an important role in restraining the house price (Ferrero, 2015). The value of the collateral is less than that of outstanding loans. Even if borrowers are affordable for repayment, they will take the initiative to default to avoid losses. This rational default leads to the rise of initiative default probability (Fang et al., 2016). The decline in credit quality causes banks to suffer losses potentially. That is, banks are subject to increased credit risk with the falling house price. On the other hand, the State Council prohibits the real estate enterprises from initial public offerings (IPO) and refinancing after this promulgation. Issuing bonds requires higher corporate qualifications and is not applicable to small and medium-sized enterprises. Bank credit becomes the main source of financing for real estate enterprises during 2012 (Xu & Chen, 2012). However, low house price leads

[1] Data source: National Bureau of Statistics (http://www.stats.gov.cn).
[2] Data source: China Banking and Insurance Regulatory Commission (http://www.cbirc.gov.cn).
[3] We also test the causality relationship by using the rolling-window widths of 20-, 28- and 32-, and our results show consistency.

Table 1
Full-sample Granger-causality tests.

	H0: HP does not Granger cause CR		*H0: CR does not Granger cause HP*	
Tests	*Statistics*	*p-value*	*Statistics*	*p-value*
Bootstrap LR test	0.526	0.913	0.823	0.844

Note: The null-hypothesis is that no-causal relationship exists between the variables.

Table 2
Parameter stability tests.

	HP Equation		CR Equation		VAR system	
	Statistics	p-value	Statistics	p-value	Statistics	p-value
Sup-F	62.416***	0.000	156.340***	0.000	17.964**	0.020
Mean-F	23.963***	0.000	28.386***	0.000	11.243**	0.034
Exp-F	28.048***	0.000	75.095***	0.000	7.445**	0.050
L_c^b					2.822**	0.030

Notes: *, **, *** Denote significance at the 10%, 5% and 1% level, respectively. Hansen–Nyblom parameter stability test for all parameters in the VAR jointly. These tests are used by R software.

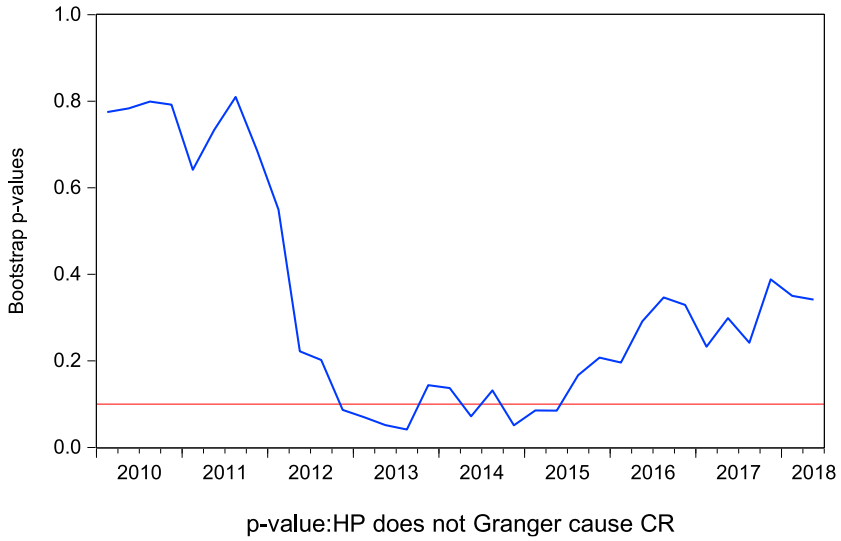

Fig. 1. Bootstrap *p*-value of rolling test statistic testing the null that HP does not Granger cause CR.

to a reduced supply of credit and a decrease in operating cash flows of enterprises (He & Wu, 2016). Meanwhile, the People's Bank of China (PBOC) raises the benchmark interest rate in 2013 and the pressure of enterprise on repaying is further amplified. Capital liquidity is threatened by financing difficulty and shrinking capital reflows, which causes more delinquency and default on bank credit (Tang & Wang, 2017). The credit quality of real estate enterprises deteriorates with falling house price and credit constraints and the credit risk of banks are accumulating. This result is consistent with the option-based model (Foster & Van Order, 1984) which indicates that the probability of default will rise when house price goes down, causing the accumulation of credit risk of banks.

In 2014:Q4-2015:Q2, the real estate market remains distressed in China. Although the GDP reaches 42 trillion yuan in the first three quarters in 2014, which achieves an increase of 7.4% compared with last year, the growth rate of real estate development investment drops sharply. It is obvious that the real estate industry has dragged down the growth of the economy. On the one hand, due to the deviation of developers' expectation and the toilless availability of investments, the real estate market undergoes overdeveloping and the inventory of houses is accumulating (Zhao et al., 2017). Price-off promotions are implemented but the trading volume does not react, which leads the disequilibrium of the real estate market and a decline in house price. Although PBOC announces to decrease the benchmark interest rates of loans to stimulate the market in November 2014, the downward trend in house price is still unavoidable causing that real estate enterprises are strapped for capital. The lack of profitability and decreasing capital liquidity lead to the decline of the debt repayment capacity of small and medium-sized enterprises (Tang & Wang, 2017). Hence, banks are confronted with high credit risk. On the other hand, in the face of falling house prices, the borrowers of mortgage loans are less confident about the future of real estate market, and the value of the collateral also decreases (Zheng et al., 2016). While banks are tightening credit, the quality of loans also declines. Inevitably, the default rate of house mortgage loans is rising (Niinimäki, 2009) and the accumulation of non-performing loans makes credit risk rise.

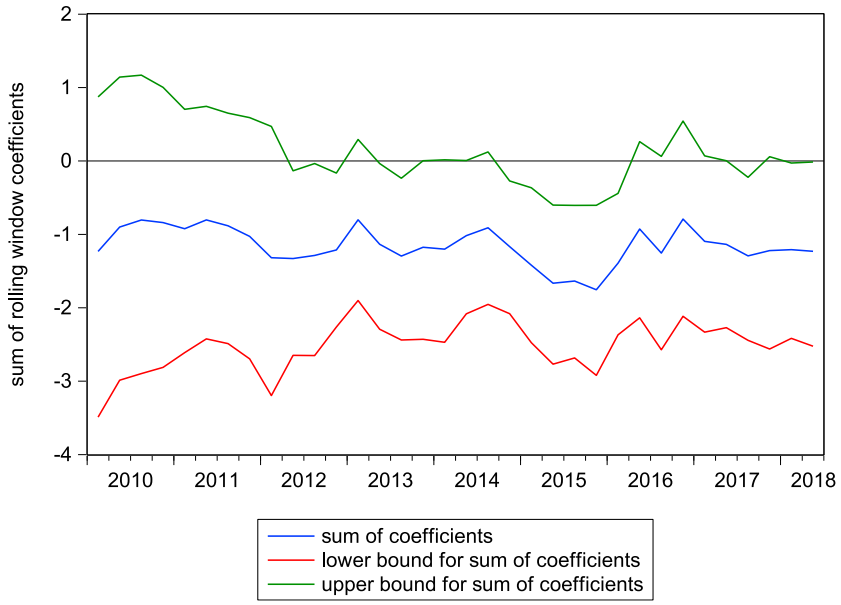

Fig. 2. Bootstrap estimates of the sum of the rolling window coefficients for the impact of HP on CR.

Figs. 3 and 4 highlights the *p*-values of the *LR* statistics and the coefficients respectively. We find that CR has a positive impact on HP in 2016:Q1-2017:Q2. In early 2016, the PBOC adjusts the minimum down payment ratio to 25%, but local governments can lower it by 5% as appropriate. The PBOC's long-term loan rate remains at a relatively low level. Meanwhile, the local governments begin to loosen the restrictions on house purchase. These policies stimulate the demand of house purchase and the expansion of housing mortgage loans, with more than 40% of incremental consumption loans flowing into the housing mortgage loans in 2016 (Cao et al., 2018). However, due to excessive credit expansion, speculative real estate loans are not effectively restricted (Yang et al., 2017). These speculative purchases use bank loans to increase leverage in order to earn profit from the frenzy markets. The ability of repayment is grossly overvalued by banks (Li et al., 2018). The more credit risk is exposed because of the higher probability of suffering losses. As a result of the rise in credit risk caused by the speculative purchase, the house price is soaring with the surge of trading volume (Yan & Hongbing, 2018). However, the rise in house price is attributed to the irrational behaviour of banks rather than fundamental-driven (Zhi et al., 2019). Hence this increasing price attributes to the accumulation of credit risk of banks. Our results are consistent with Himmelberg et al. (2005) and Anundsen et al. (2016), which indicate that the irrationality of bank credit expansion induce the rising credit risk, thus the price bubble is generated.

Based on the above analysis, we find that only when the house price declines at a rising speed can the credit risk be increased. It is

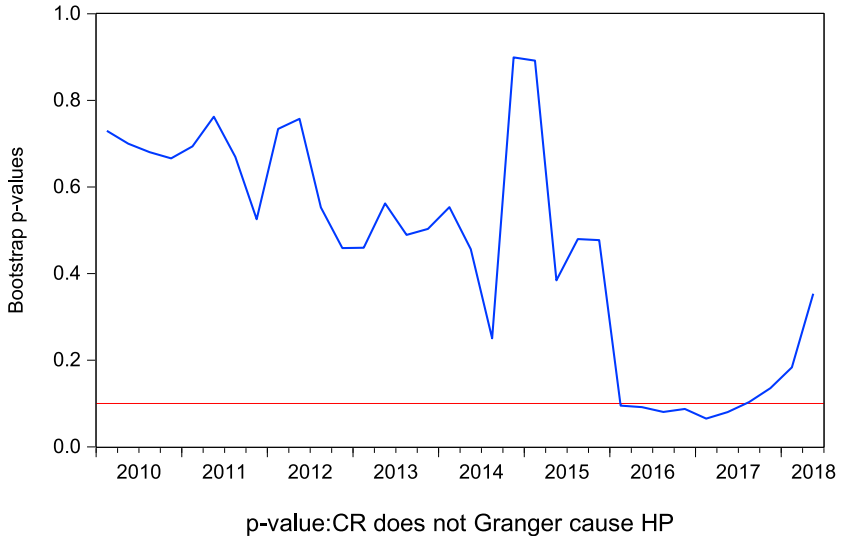

Fig. 3. Bootstrap *p*-value of rolling test statistic testing the null that CR does not Granger cause HP.

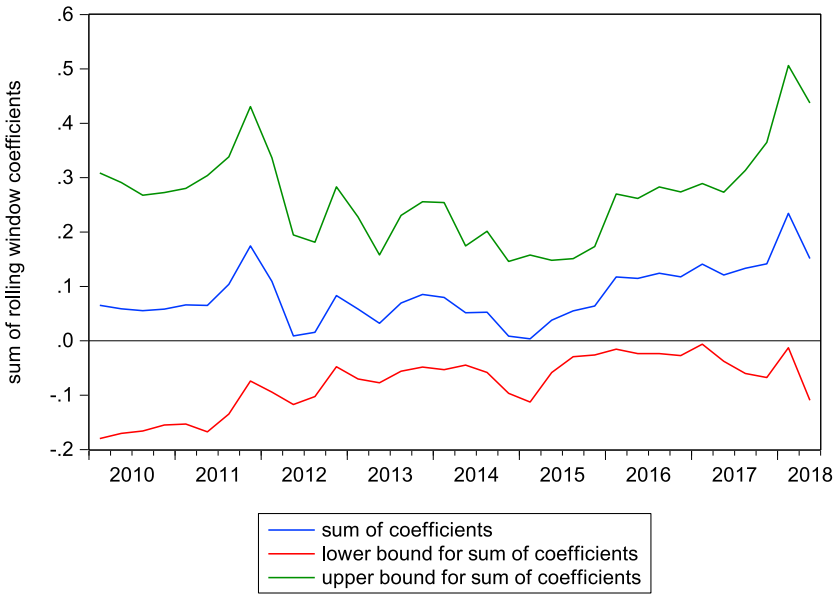

Fig. 4. Bootstrap estimates of the sum of the rolling window coefficients for the impact of CR on HP.

believed that under the current conditions in China, although house price does not endanger the outbreak of credit risk, the potential build-up of credit risk is likely to continue. Starting from 2019, the real estate market enters a moderate period as China's economic growth slows (Zhang et al., 2019). The growth of house sales starts to decline and even stagnates in first-tier cities, thus house price shows a slow growth then becomes stable (Yang et al., 2018). House buyers are reluctant to take out mortgages at a high house price because they have to afford higher interest payments (Cai et al., 2019). On the other hand, due to the promotion of the new urbanization, more urban and rural buyers apply for mortgage loans. the overall repayment ability of buyers shows a potential downward trend, which lead the bank's evaluation system for personal credit to be more strict (Kostka, 2019). Hence mortgage loan growth reaches the lowest level in recent years (Li & Gao, 2019). Because the house price does not manifest a decline in the short term, the rational default will not rise (Fang et al., 2016). At the same time, real estate enterprise operation is stable as the speed of capital reflux achieves the expectation (Liu et al., 2018). These main factors keep the credit risk from exploding in the short term. However, in the long run, banks still face rigorous challenges of credit risk management. Chinese commercial banks have no diversified profit channels and the profitability is limited (Arestis & Jia, 2019). Income from loan interest still accounts for a large proportion. Compared with large international commercial banks, Chinese commercial banks barely have non-interest income in intermediate business items (Fang et al., 2019). Because of information asymmetry, commercial banks cannot distinguish high credit customers from high risk customers (Ye et al., 2019). Chinese real estate enterprises have narrow direct financing channels and less self-owned capital. Funding source of enterprises mainly relies on bank credit. This intense concentration results in the increasing possibility of bank's potential credit risk accumulation (Xu & Chen, 2012). Moreover, in the disposal of collateral, banks do not have a comprehensive response measures. Once the default occurs, most collateral value is far from sufficient to make up for the loss (Zhou et al., 2019).

PBOC encourages commercial banks to expand credit to support the real economy as trade frictions with the U.S. intensify in 2019. Excessive mortgage lending by banks leads to the accumulation of credit risk (Cong et al., 2019). On the other hand, in early 2020, the slowdown of economic development triggered by the Coronavirus Disease (COVID-19) pandemic means lower profits for real estate companies and higher debt servicing burdens. This would not only lead to more defaults and lower investor confidence, but could also result in a wide credit squeeze. In addition, if commercial banks in developed countries are impacted by deteriorating asset quality and cut back on credit sharply, the liquidity in the interbank market will dry up. Crisis-hit banks in developed economies will pull money out of emerging economies. These banks are large lenders and pivots of the global financial system. There will be huge international spillovers. With financial markets more interconnected recently, Chinese banks will be in danger if loan defaults destabilize the banking systems of developed economies.

Based on bootstrap sub-sample rolling-window estimation, we obtain a perception on time-varying relationship between house price and credit risk in China. However, the causality between house price and credit risk is not stable over time and will not exist in the long term. Credit risk will outbreak with falling house price on account of the default of real estate-related loans. Moreover, the irrationality of credit expansion threatens the risk management of banks themselves by stimulating the speculative purchase. We also give a prospective sight in present situation of credit risk level which banks may confront. The results of this paper provide references for future regulation of the real estate industry and banks in China. To summarize, to explore non-linear relationship between house price and credit risk, not necessarily in the case of China, serves as a continuous stimulus for future studies. For instance, we should consider whether different levels of house price have an impact on credit risk in China, which this paper does not examine. These further works can help capture the relationship between house price and credit risk comprehensively.

6. Conclusion

We examine the causality between credit risk and house price in China via bootstrap full-sample Granger-causality test. The test shows that there is no evidence of a bidirectional relationship between the variables. We find that there are bidirectional causal relationships between house price and credit risk by using the approach of the sub-sample Granger causality test. The results note that the falling house price increases the credit risk due to the default of real estate-related loans. This conclusion generally conforms to the option-based model of credit risk (Foster & Van Order, 1984) which conducts the relationship between house price and credit risk. Meanwhile, credit risk is accumulated when bank credit expansion leads to speculative real estate loans. In addition, credit policies and interest rates have a significant impact on house price during certain periods, which drives the changes in credit risk. We also indicate that in current situation of mortgage growth slowing down and moderate real estate market, it does not make sense that credit risk will erupt. But it is unimpeachable for Chinese banks to keep a level of vigilance in managing credit risk. Banks should strengthen the examination of personal credit certificates to prevent speculative loans. The authorities should consider the impact on the quality of bank loans when formulating policies to control the house price.

CRediT authorship contribution statement

Chi-Wei Su: Conceptualization, Methodology, Software. **Xu-Yu Cai:** Data curation, Writing - original draft. **Meng Qin:** Writing - review & editing. **Ran Tao:** Visualization, Investigation. **Muhammad Umar:** Writing - review & editing.

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