

## IMPACT OF MAJOR EVENTS ON HOUSING PRICES IN HANGZHOU BASED ON REGRESSION DISCONTINUITY

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**Abstract.** Based on the regression discontinuity method, housing transaction price data of Hangzhou at the community level were used to assess the impacts of a series of major events on housing prices in Hangzhou. The results show that the 2008 financial crisis had the strongest negative impact on housing prices, with prices decreasing by about 20%. Winning the right to host the G20 summit did not significantly impact housing prices, while holding the summit caused an increase in prices (about 10%). The first implementation of the home purchase restriction (HPR) caused a decreasing discontinuity of housing prices. Cancellation of the HPR did not cause a discontinuity effect, but the trend changed from negative to positive, and resumption of the HPR for local residents yielded the largest drop in housing prices, resulting in a 10% downward cut-point. However, the impact time was relatively short and did not change the rapid rising trend of housing prices.

**Keywords:** major events, housing prices, regression discontinuity, financial crisis, Hangzhou G20 summit, home purchase restriction policy.

### Introduction

Since the marketization reform in 1998, China's real estate market has developed rapidly. In addition to the unwavering demand for housing, projected demand has contributed to a significant increase in housing prices over recent years. Growing attention is also directed towards major events that lead to fluctuations in housing prices.

The real estate market is closely linked to the financial market and as such, heavily influenced by inflation, bank credits, short-term interest rates, and spreads related to mortgage financing (Katrakilidis & Trachanas, 2012). This implies that fluctuations in financial markets can also significantly impact the real estate market. When the financial crisis originating in the United States in 2008 spread to China, housing prices plummeted in many cities. In response, to stimulate market consumption, the Chinese government adopted a series of bailout measures, such as the “Four Trillion” stimulus plan, which achieved a rebound of the real estate market.

In addition, because of social and cultural influences as well as high value-added potential, residential housing has always been a hot spot for both investment and speculation. To curb speculation and investment demand in cities with fast rising housing prices, the State Council issued a series of regulation measures in 2010, including

home purchase, loan, and price restrictions. Unlike previous regulations, such as adjustments of mortgage rates and down payment ratios, which had minimal effect, this round of regulation limited market demand directly. Many research results showed that this harsh nationwide regulation cooled China's real estate market to a certain extent. In cities that implemented HPR regulation policies, housing prices clearly decreased compared with cities that did not implement these (Qiao, 2012; Han et al., 2014). At the same time, scholars pointed out that while the implementation of these policies can reduce housing prices, the effect remains limited, proposing that the adjustment of the supply side the market may yield a “high prices and low volume” development (Wang & Huang, 2013).

Hangzhou, the capital city of Zhejiang Province, has a relatively mature real estate market. Due to its developed economy and pleasant environment, housing prices in Hangzhou are among the highest in China, second only to first-tier cities such as Beijing, Shanghai, and Shenzhen. In February 2015, Hangzhou won the right to host the G20 summit, which was held in September 2016. Hangzhou's international competitiveness and influence significantly improved, and housing prices also increased significantly. External economic events, related government regulatory policies, and the hosting of major international

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conferences were all followed by a certain degree of fluctuation in housing prices in Hangzhou, providing an ideal condition for studying the impact of major events on housing prices.

There are still relatively few applications of regression discontinuity methods in the field of real estate research, among which only few studies evaluated home purchase restriction (HPR) policies in Chinese cities. This paper applies the regression discontinuity method to different major events, including the financial crisis, the Hangzhou G20 summit, and governmental regulatory policies. The house transaction price data of Hangzhou was analyzed at the community level to explore the impact of major events on housing prices. A relatively new policy evaluation method is used to verify the direction, magnitude, and extent of influences on housing prices using historical data. This result can be compared with the results of studies on other cities or using other methods, and also provides a reference for policy formulation. Furthermore, the feasibility of the regression discontinuity method in the study of major events is further verified.

The rest of this paper is organized as follows: Section 1 reviews the literature related to the impact of major events on housing prices using the regression discontinuity method. Section 2 describes the data and outlines the applied regression discontinuity methodology. Section 3 presents the results of the empirical analysis, and the last section concludes the paper.

## 1. Impact of major events on housing prices and the regression discontinuity method

The literature does not provide a consistent definition of a major event. In the field of tourism and marketing, a “mega-event” refers to a short-term high-profile event with a fixed duration (Ritchie & Yangzhou, 1987). The hosting of sporting events such as the Olympic Games, the Football World Cup, and the world expo can lead to increased tourism, improvements in urban infrastructure, create jobs, and cause other economic growth and prosperity (Yamawaki et al., 2020). It is well acknowledged that the Olympic Games are not only sporting events, but also closely linked to economic objectives (Hiller, 1998). These mega-events are commonly conceived as essentially economic initiatives. The decision to host an event is legitimized in economic terms. At the same time, hosting world sporting events also has political implications. The events themselves are a reflection of political decisions. Seeking to host major events becomes part of a deliberate policy strategy for many cities to stimulate local economic growth (Burbank et al., 2002). In terms of the impact on the economy, such mega-events bear resemblance to events in the financial and economic context. The term “events” in financial research usually refers to specific events that impact stock prices, mainly used for mergers, acquisitions, and product launches or recalls. Moreover, regulatory policies and external emergencies such as the COVID-19 pandemic that may impact the dependent

variable of interest are often foci of financial event studies (Heyden & Heyden, 2021; Hoesli et al., 2017). Similarly, in the field of real estate research, a number of scholars have included regulatory policies and exogenous events that significantly impact real estate prices in the category of major events. Based on data of Hangzhou of 2007–2011, the empirical analysis of Ruan et al. (2012) used integrated empirical mode decomposition and Bai-Perron multi-cutoff detection, and showed that major events generated stepwise changes in housing prices. Zhang et al. (2017) used Circle-Frequency filtering to investigate the impacts of major events on residential prices and volume fluctuations. They showed that the financial crisis, bailout policies, and other governmental regulatory policies significantly impacted both housing prices and trading volumes.

Long-term housing prices are closely related to macroeconomic fundamentals and are affected by factors such as population, per capita disposable income, interest rates, inflation, and credit policies (Adams & Füss, 2010; Bork & Møller, 2018). In 2008, a global financial crisis broke out and in response, housing prices plummeted in many countries including China. Reinhart and Rogoff (2009) compared data from 21 countries that experienced past financial crises and found that house prices fell by 35.5% on average, lasting an average of six years. For the Chinese mainland, research of Wang et al. (2014) and Huang and Gu (2011) showed that the subprime mortgage crisis led to a decline of China’s real estate development climate index from 106.59% in November 2007 to 94.74% in March 2009. The housing prices in 70 large and medium-sized cities in China decreased significantly.

The financial policies, land policies, and market regulation policies related to the real estate market often directly or indirectly impact housing prices. The existing literature shows that monetary policy can effectively restrain housing price bubbles (Gupta et al., 2010). The government’s land supply control will reduce the elasticity of housing supply, resulting in an increase of housing prices (Gyourko & Molloy, 2015; Hilber & Vermeulen, 2016). The intensive regulation policies the Chinese government imposes on the real estate market largely affect housing prices, and changes in economic fundamentals cannot stably explain the observed fluctuations of housing prices (Yu, 2010).

In addition, the bidding on and holding of major international events, such as the Olympic Games, Asian Games, World Expo, and the G20 summit, often significantly impact local housing prices. These global sporting events play a function to catalyze and consolidate urban reconfiguration activities such as public transportation construction, urban renewal, and purposeful development prior to the event (Gaffney, 2016; Yamawaki et al., 2020). Kontokosta (2012) applied the adjusted interrupted time-series method to study the housing prices of six cities that hosted the Olympic Games from 1984 to 2000. The impact of housing prices in different cities was found to depend on the degree of urban planning and the scale of relative investment. Kavetsos (2012) used the difference-

in-difference method to study the successful bid for the 2012 Olympic Games in London, and the results showed that the housing prices of the hosting city increased by 2.1–3.3%, and housing prices of the residential area within 3 miles from the main stadium increased by about 5%. Adverse events can also affect the housing price. Francke and Korevaar (2021) used a modified repeat sales model to study the short- and long-term effects of pandemics on the housing market. The large impact of infectious diseases on housing prices in the short run suggests a rapid decline in housing investment demand when a negative event emerges. However, the rapid return of house prices and rents to trends prior to the pandemic also reflects a high degree of resilience in housing markets in cities such as Paris and Amsterdam.

The event study method is often used to observe the extent of the impact of a particular event. Heyden and Heyden (2021) employed the method and a sample of companies in the United States and Europe to analyze stock market reactions to the first case and first death related to COVID-19. A considerable number of papers in finance research have applied the event study methodology. By identifying specific events and event cycles, stock return data from the financial markets were used to analyze abnormal returns due to events. Hoesli et al. (2017) employed an event study approach to investigate the impact of financial regulatory policies on stock returns of real estate companies. They used a dummy variable approach to indicate events and measure the effect of regulatory events on the day they are announced by calculating abnormal returns for each company. Similarly, Nanda and Ross (2009) estimated the impact of the Property Condition Disclosure Law on house prices. By treating the adoption of the seller disclosure law as an “event”, they tested whether an “abnormal return” is generated. The basic idea of the event study method is to estimate abnormal stock returns or abnormal asset price movements during the event window, which requires the setting of a corresponding estimation window. Moreover, event studies are often used in situations where a market index provides a benchmark to compare the returns of assets.

Unlike the event study method that requires setting an estimation window and a baseline return for comparison, while not requiring identification of a control group corresponding to the treatment group as in difference-in-difference method, the regression discontinuity method estimates the impact of an event by observing the abrupt change at breakpoint. Regression discontinuity was first introduced by Thistlethwaite and Campbell (1960) to examine whether students’ academic honors enhance their future academic achievements. The method enables analysis of policy implementation effects without the need for a control group and is considered an effective way to test causality. Hahn et al. (2001) theorized regression discontinuity, put forward the key hypothesis, and divided regression discontinuity into the two categories of precise regression discontinuity (where the critical cutoff is de-

termined) and fuzzy regression discontinuity (where the probability of samples on both sides of the critical cutoff is monotone random). Imbens and Lemieux (2008), and Lee and Lemieux (2010) described the origin, background, applied studies, applicability conditions, and empirical steps of regression discontinuity in detail from an econometric perspective. Regression discontinuity has been applied to the fields of education (Gibbons et al., 2012), economics (Lee & Lemieux, 2010), and political science (Dell et al., 2018).

In real estate research, Karamon et al. (2017) used regression discontinuity to examine the impact of refinancing on mortgage defaults before and after the home affordable refinance program. The impact of the HPR policy on housing prices has also been studied with the regression discontinuity method, but the conclusions are inconsistent. Zhang et al. (2015) found that the purchase restriction in Shanghai significantly reduced the regional prices of newly built and second-hand houses, while Li et al. (2010) found that the HPR policy promoted the rise of second-hand house prices in Beijing suburbs. The implementation effect of the policy shows certain regional heterogeneity (Wu, 2019). The effect is more significant in western cities than in eastern and central cities (Li, 2015), and the short-term and long-term effects on prices differ (Liao et al., 2018). Sun et al. (2017) used parametric regression discontinuity to examine the housing market in Beijing, the first city to implement the HPR. The results showed that purchase restrictions led to a 17–24% drop in the prices of second-hand houses in Beijing and a 50–75% drop in the transaction volume. Unlike the previous mild or even small effect of frequent regulation, the purchase restriction policy is a severe intervention in the market, and there is a clear implementation time, resulting in a more visible drop in market sentiment. Given that both policy implementation and market response vary between cities, the effect of the policy in Hangzhou city remains to be examined.

The existing literature on the impact of major events on housing prices has basically confirmed the negative impact of the financial crisis on housing prices. However, certain major international activities can improve urban transportation, attract additional investment, and boost housing prices. The government’s regulatory policies, including monetary policy, land supply restrictions, HPR, institutional policies, and interest rate adjustment policies, will also significantly impact housing prices. As most studies only apply regression discontinuity to evaluate a single policy, the present study concentrates on longitudinal house price fluctuations in the city of Hangzhou, especially abnormal fluctuations. As a developed city in an emerging market, the housing market of Hangzhou is characterized by high price levels, strong speculative demand, and various ongoing regulatory policies. Based on dramatic changes in house prices and transaction volumes, combined with external events and major regulatory policies, this paper identifies several event breakpoints. Major

events that occurred within the sample time interval are summarized, regression discontinuity is applied to examine the impact of different major events on housing price inflations, the corresponding key assumptions are strictly satisfied, and robustness tests are conducted. This paper examines the trend and volatility of housing prices in the city, as well as the extent of the impact of various major events.

## 2. Data and model

The data used in this paper are the monthly average prices of newly built houses in Hangzhou at the community level from January 2006 to March 2019. The dataset contains 1,129 communities and 32,358 observations. The scope includes eight administrative districts in the main urban area of Hangzhou. Based on the reviewed literature, a major event is defined as an economic or policy event that significantly impacts the real estate market. By assessing monthly changes in housing prices and transaction volumes, the major events identified during the study period include the 2008 financial crisis, the successful bidding and holding of the Hangzhou G20 summit, as well as the implementation, cancellation, resumption, and upgrade of the HPR (Figure 1).

The housing prices data were obtained from the China Real Estate Information Corporation database, and the control variables about points of interest were calculated using the digital map data provided by the Hangzhou Geographic Information Center. Certain location characteristic variables and neighborhood characteristic variables were calculated in ArcGIS. In reference to previous research and considering the availability of data, the control variables used in this paper include community characteristics, location characteristics, and neighborhood characteristics. The descriptive statistics of variables are shown in Table 1. Architectural features are expressed using the plot level greenery ratio and car parking ratio. Among location variables, the distance from the famous landscape feature of West Lake was considered, but also the traditional downtown, and the distance from the city's new central business district of Qianjiang New Town. The neighborhood characteristic variable mainly utilizes the distance to the nearest subway station, the number of bus stops, universities, parks within the surrounding 1 km, and the number of shopping centers within 3 km.

Informed by several attempts to combine the model goodness of fit and the significance of control variables, this paper takes a logarithmic form for the distance variable and a linear form for the other variables among control variables.

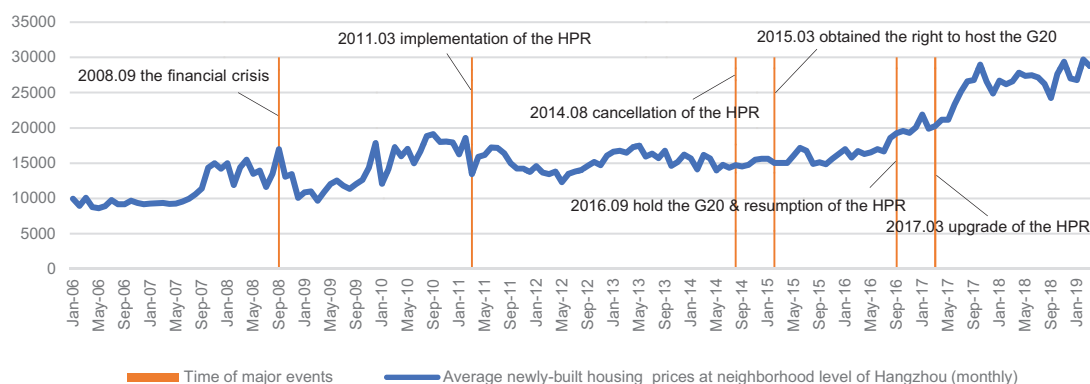


Figure 1. Monthly average housing prices and major events in Hangzhou (from the China Real Estate Information Corporation)

Table 1. Descriptive statistics of variables

Variable	Description	Samples	Mean	Std. Dev.	Min	Max
<i>Price</i>	Monthly average housing prices	32358	16656.43	10648.04	1127	100456
<i>Green</i>	Greenery ratio of the community plot	32358	32.08	5.43	3	70
<i>Parking</i>	Parking ratio of the community	32358	1	0.33	0.17	3.6
<i>LdisWL</i>	The log of distance to West Lake	32358	2.41	0.63	-1.34	3.75
<i>LdisQJ</i>	The log of distance to Qianjiang CBD	32358	2.51	0.62	-0.08	3.78
<i>Metro</i>	The log of distance to the nearest Metro station	32358	0.86	1.18	-2.7	3.29
<i>Bus</i>	Number of bus stops within 1 km	32358	24.26	19.5	0	120
<i>University</i>	Number of universities within 1 km	32358	0.12	0.51	0	5
<i>Parks</i>	Number of parks within 1 km	32358	0.05	0.24	0	4
<i>Shopping</i>	Number of shopping centers within 3 km	32358	2.83	2.89	0	22

Although treatment effects can still be estimated without bias and consistently without using control variables in the regression discontinuity, it is still necessary to include control variables when conducting robustness tests. In reference to Lee and Lemieux’s (2010) review on regression discontinuity, this paper uses both parametric and non-parametric regression discontinuity methods for the empirical study and the results of both are compared. The formulas are as follows:

Parametric form (Lee & Lemieux, 2010):

$$P_i = \alpha + \delta D_i + \sum_{k=1}^K \beta_k (x-c)^k + \sum_{k=1}^K \gamma_k (x-c)^k D_i + A W_a + B \ln W_b + \varepsilon_i \tag{1}$$

Nonparametric form (Chen, 2014):

$$\min_{\alpha, \beta, \delta, \gamma} \sum_{i=1}^n K \left[ \frac{(x_i - c)}{h} \right] \left[ P_i - \alpha - \delta D_i - \beta(x_i - c) - \gamma(x_i - c) D_i - A W_a - B \ln W_b \right]^2, \tag{2}$$

where:  $P_i$  represents the average monthly price in a certain community,  $x$  is the grouping variable, i.e., the monthly time, incremented by 1 for each period beginning with  $x = 1$ , which represents January 2006.  $c$  indicates when a major event occurs; if  $x \geq c$ , the value of the dummy variable  $D_i$  is 1, otherwise, it is zero. The coefficient  $\delta$  is the impact of major events on housing prices that need to be estimated.  $W_a$  refers to control variables using the linear form, and  $W_b$  refers to control variables using the logarithmic form.

### 3. Empirical analysis

#### 3.1. The 2008 financial crisis

In 2008, the global financial crisis originating from the subprime mortgage crisis in the United States had a significant negative impact on China’s real estate market.

Data from the National Bureau of Statistics show that the nationwide residential sales area decreased by 20.3% year on year, and the sales value decreased by 19.35%, constituting the largest decrease since 1998. This paper assumes September 2008 as the time of this financial crisis. Many studies have assessed house price changes based on this point in time (Zhang et al., 2017; Ruan et al., 2012). Moreover, at that time, the fourth-largest investment bank in the United States, Lehman Brothers Holdings Inc., filed for bankruptcy protection. In addition, the stock markets of all major economies around the world basically had a large decline in that month, indicating that the financial crisis had reached a very serious degree.

The regression discontinuity method applies the strict assumption that grouping near the cutoff is random, reflecting the fact that the density function of the grouping variable must be continuous on both sides of the cutoff. Before assessing empirical evidence of regression discontinuity, the continuity of the density function of grouping variables should therefore be tested. This paper specified that the financial crisis occurred in September 2008, corresponding to the cutoff  $c = 33$ . The regression discontinuity density test showed that the  $p$ -value at this point was 0.1024, thus accepting the null hypothesis that the density functions of grouping variables are continuous and not artificially manipulated. Regression discontinuity could be applied to this point.

Firstly, parametric regression is performed on the sample, adding all control variables, using a first-order polynomial to calculate, with the optimal bandwidth  $h$  of 12.34 under a rectangular kernel. The results are shown in Table 2. Except for the greenery ratio, all control variables are significant. The coefficient of  $D$  showed that there was a significant drop in housing prices of 2599.9 ¥/m<sup>2</sup> (about 20%)

Table 2. Impact of the 2008 financial crisis using parametric regression

	Non-standardized coefficients		<i>t</i>	Sig.
	<i>B</i>	Standard Error		
<i>D</i>	-2599.941***	418.023	-6.22	0.000
<i>X-c</i>	254.521***	45.310	5.62	0.000
<i>D*(X-c)</i>	-118.515**	56.590	-2.09	0.036
<i>Green</i>	0.695	14.608	0.05	0.962
<i>Parking</i>	3208.828***	297.397	10.79	0.000
<i>LdisWL</i>	-3482.325***	248.623	-14.01	0.000
<i>LdisQJ</i>	-2939.503***	225.137	-13.06	0.000
<i>Metro</i>	-277.728**	112.490	-2.47	0.014
<i>Bus</i>	-14.899**	7.364	-2.02	0.043
<i>University</i>	1634.003***	161.033	10.15	0.000
<i>Parks</i>	6558.886***	287.254	22.83	0.000
<i>Shopping</i>	-87.235*	44.609	-1.96	0.051
(Constant)	25359***	894.113	28.36	0.000
Adjusted R <sup>2</sup>	0.5647			

Note: \*\*\*, \*\*, and \* represent significance levels at the 1%, 5%, and 10% levels, respectively.

in September 2008. However, after this breakpoint, housing prices started to rise gradually and exceeded the previous peak about 2 years later (Figure 2).

To further estimate and test the impact of the 2008 financial crisis on housing prices, the influence of different orders, different bandwidths, and whether to add control variables or not were considered. Both the parametric and non-parametric regression results are shown in Table 3. In the parametric model, the result of a first-order polynomial with the addition of covariates is consistent with the result shown in Table 2. Regardless of whether control

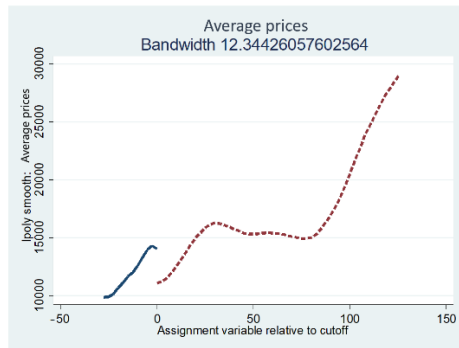


Figure 2. Impact of the 2008 financial crisis

variables are added, the drop is apparent in the parametric model of the first-order polynomial. However, the housing price is not significantly affected in the second-order polynomial model. In the non-parametric model, when using different parameters, the estimated processing effects are all significantly negative. Overall, the results are relatively robust, indicating that the housing price decreased significantly in September 2008.

To ensure validity of the regression discontinuity results, it is necessary to test the continuity of each control variable on both sides of the cutoff. The continuity of each control variable at  $c = 33$  is shown in Table 4. None of the coefficients of these control variables are statistically significant, and therefore, the null hypothesis of continuous control variables is accepted, indicating that each control variable has no breakpoint at  $c = 33$ .

The above results show that there was a significant drop in housing prices in Hangzhou in September 2008, where housing prices decreased by approximately 20%, which can be attributed to the 2008 financial crisis. After that, the housing prices still maintained their growth trend, but the growth rate decreased. Two years later, housing prices exceeded the previous peak, which may be related to market rescue policies the government implemented. To cope with the pressure induced by the financial crisis, the state

Table 3. Impact of the 2008 financial crisis using parametric and non-parametric models

Parametric regression discontinuity results	Covariates	Bandwidth	Polynomial order	
			1 <sup>st</sup> -order	2 <sup>nd</sup> -order
	Yes	1 h	-2599.941***	-46.395
No	1 h	-2956.976***	-186.417	
Non-parametric regression discontinuity results	Covariates	Bandwidth	Kernel	
			Triangular (h = 15.716)	Rectangular (h = 12.344)
	Yes	1 h	-2462.349***	-2599.941***
	No	1 h	-2896.605***	-2956.976***
	No	0.75 h	-1762.191**	-2086.832***
No	1.25 h	-3794.687***	-4298.590***	

Note: \*\*\*, \*\*, and \* represent significance levels at the 1%, 5%, and 10% levels, respectively.

Table 4. Density continuity test of control variables

	Coeff.	S. D. Error	Sig.
Green	0.339	0.52	0.515
Parking	-0.006	0.03	0.830
LdisWL	0.072	0.06	0.224
LdisQJ	0.058	0.06	0.332
Metro	0.053	0.10	0.583
Bus	-1.314	1.43	0.357
University	-0.004	0.06	0.940
Parks	0.000	0.04	1.000
Shopping	-0.086	0.28	0.759

government launched the “Four Trillion” stimulus plan in November 2008. The Hangzhou municipal government introduced the corresponding stimulus policy in October 2008, adjusting both the real estate demand and taxes.

### 3.2. The G20 summit

The Group of 20 (G20) is an international economic cooperation forum attended by the leaders of the 20-member countries. In March 2015, Hangzhou successfully won the right to host the 11<sup>th</sup> G20 summit, which was held in September 2016. The housing prices also experienced apparent increases before and after the summit was held. This paper studies the impacts of winning the right to host the G20 and the holding of the summit as two time points of this major event.

The time of winning the right to host the G20 summit corresponds to  $c = 111$ , and the time of holding the summit corresponds to  $c = 129$ . The result of continuity test of the density function of the grouping variable shows that the  $p$ -values are 0.7700 and 0.2372, respectively, both of which exceed 0.1, suggesting that the density function of the grouping variable is continuous.

The results of models using different parameters are shown in Table 5. Regarding the major event of winning the right to host the G20 summit, only regression results

under optimal bandwidth with the inclusion of covariates show a significant upward jump (the significance level is only 10%). The results are not robust overall. At the time of holding the G20, except for the results of second-order polynomial regression excluding covariates in the parametric model, the housing prices in September 2016 showed a significant upward jump when different parameters are used. The estimated impact is significantly positive, and the regression results are very robust.

As shown in Figure 3, no apparent jump was found in March 2015, but the price trend changed, and after winning the right to host the summit, prices started to follow a clear upward trend. Housing prices showed significant upward discontinuity in September 2016, with an increase of 1939.1 ¥/m<sup>2</sup> (about 10%). At the same time, the continuity test of the control variables showed that none of the control variables had a cutoff at  $c = 129$ .

The real estate market in Hangzhou was particularly hot in the month when the summit was held (September 2016), with 21,891 units of new house transactions, representing an increase of 105.6% year-on-year. The number of second-hand houses sold reached a record high of 9,334 units. According to the regression discontinuity results above, in September 2016, a significant upward jump in housing prices happened, with an increase of

Table 5. Impact of the G20 summit using parametric and non-parametric models

			Obtaining the right (2015.03)		Holding (2016.09)	
Parametric regression discontinuity results	Covariates	Bandwidth	Polynomial order		Polynomial order	
			1 <sup>st</sup> -order	2 <sup>nd</sup> -order	1 <sup>st</sup> -order	2 <sup>nd</sup> -order
	Yes	1 h	359.558*	-3.429	1939.114***	1011.499***
No	1 h	-121.974	-346.968	1842.753***	1116.633	
Non-parametric regression discontinuity results	Covariates	Bandwidth	Kernel		Kernel	
			Triangular (h = 21.179)	Rectangular (h = 16.635)	Triangular (h = 15.025)	Rectangular (h = 11.802)
	Yes	1 h	339.299*	359.558*	1882.380***	1939.114***
	No	1 h	-58.547	-121.974	1757.223***	1842.753***
	No	0.75 h	-223.924	-295.492	1570.957***	1899.614***
No	1.25 h	112.095	117.947	1821.998***	1800.068***	

Note: \*\*\*, \*\*, and \* represent significance levels at the 1%, 5%, and 10% levels, respectively.

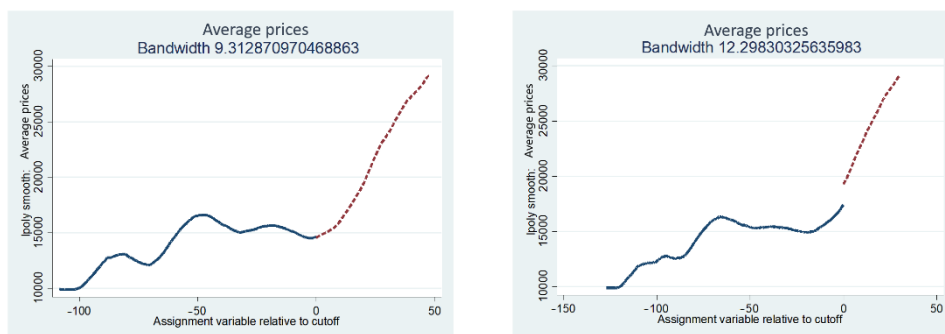


Figure 3. Impact of the G20 summit (left: winning the right, right: holding the G20)

1011.5–1939.1 ¥/m<sup>2</sup> (about 5–10%). In fact, due to the overheated real estate market, the Hangzhou municipal government issued an emergency resumption of the home purchase restriction policy later the same month. The impact of the resumption of this restriction likely led to the underestimation of the jump in September due to the hosting of the G20 summit.

Why could the Hangzhou G20 summit cause an increase of housing prices? The authors suggest that there are three reasons, namely urban renewal and city appearance reform, considerable infrastructure investment, and the improvement of the city's attractiveness.

In preparation for the G20 summit, the Hangzhou government implemented a host of arrangements to improve the appearance of the city. First, 2,334 roads were repaired, major attractions such as West Lake, the Canal, and the Qiantang River were renovated, thus increasing places for citizens to enjoy leisure and entertainment, and improving the urban landscape. Second, the Hangzhou government carried out and completed the environmental renovation and transformation of 605 projects in six categories, including the beautification of 264 streets, the demolition of 10 million m<sup>2</sup> of illegal buildings, the demolition of 5,615 illegal outdoor billboards, and the renovation of 9 million m<sup>2</sup> of old residential areas, old factories, and urban villages. It has been shown that urban renewal yielded 28.6% and 32% increases in housing prices around the project during construction and operation periods, respectively (Huang et al., 2019).

The effect of improving urban transportation infrastructure on housing prices has been demonstrated before (Martínez & Viegas, 2009; Mulley & Tsai, 2016). During the G20 summit, the Hangzhou municipal government also invested in infrastructure at a large scale. At the beginning of 2016, 56 transportation projects were under construction in Hangzhou, including 23 transportation construction projects, 31 high-speed entrances, and two railway entrances. Infrastructure construction and renovation had been a driving force for the increase of housing prices.

Finally, the G20 summit in Hangzhou greatly enhanced the attractiveness of the city. During the preparatory period for the summit, through media reports and publicity, Hangzhou's appearance and charm attracted an increasing number of people to the city. According to data of the Hangzhou Municipal Bureau of Statistics, the total population of Hangzhou increased by 1.72%, 2.43%, and 2.68% year-on-year in 2016, 2017, and 2018, respectively, and the increasing rates were significantly higher than those of previous years. According to a report on the dynamics of workplace flow in the second quarter of 2017 released by wow.liepin.com, Hangzhou had the highest net inflow among major cities in China, with a net inflow rate of 11.21%.

### 3.3. Home purchase restrictions

To curb housing speculation and surge housing prices, on February 28, 2011, the HPR policy began to be implemented for the first time in Hangzhou. Specifically, locally registered

residents who already own two or more residential assets in Hangzhou, and unregistered residents who own one or more residential assets or cannot provide proof of payment of one year's accumulated income tax or social insurance payment within two years in Hangzhou were not allowed to purchase further houses. The HPR policy directly interfered with the purchase behavior of the market and had an immediate and significant impact on the housing market.

In 2014, due to China's sluggish real estate market, numerous non-first-tier cities took the lead in easing purchase restrictions. Correspondingly, Hangzhou began to loosen restrictions in certain suburban areas in late July 2014. From August 29, purchasers were not required to provide proof of housing information, and purchase restrictions had been completely cancelled across the city.

On the afternoon of September 18, 2016, the Hangzhou Housing Security and Real Estate Administration Bureau resumed the HPR policy. This time, sales of housing to unregistered residents who already own one or more houses were suspended from September 19. In March 2017, the scope of the implementation of the HPR was further expanded, and the purchase restriction for unregistered residents was upgraded. More importantly, a purchase restriction for families with locally registered residents was added. Sales of newly built houses and second-hand houses to locally registered residents that already own two or more houses were suspended.

This paper studies the impact on housing prices of Hangzhou's initial implementation, cancellation, resumption, and upgrading of the HPR policy. The corresponding time points are March 2011, August 2014, September 2016, and March 2017, respectively. The continuity of the density function of grouping variables is tested for these four time points. The results show that the *p*-values are 0.2188, 0.6029, 0.2372, and 0.3186, respectively, showing that the density functions of the grouping variables are continuous at all time points of the HPR. The covariates have no discontinuity at any of the four time points.

The Hangzhou G20 summit was held at the same month when the restriction was resumed (September 2016), which was followed by a significant upward jump in the housing prices in that month according to Section 3.2. This could be attributed to the G20 summit in Hangzhou. However, it is difficult to estimate the impact of the resumption of the HPR on the housing price. Considering that the HPR policy itself may have caused a significant reduction of the transaction volume, an attempt was made to estimate the impact of the policy implementation on transaction volume, using transaction data from January 2015 to June 2019. With September 2016 as the estimated point, a non-parametric regression with a rectangular kernel function was used without inclusion of control variables. The estimated result of the transaction volume coefficient under the optimal bandwidth is -6438.93 units (significant at the 10% level), and the results are shown in Figure 4. The resumption of the purchase restriction significantly reduced the residential transaction volume in Hangzhou.



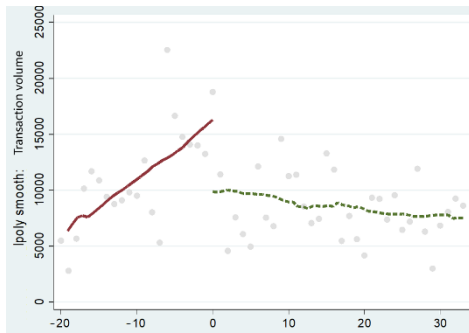


Figure 4. Impact of the resumption of home purchase restriction (HPR) on transaction volume

The results of parametric and non-parametric regressions for the first implementation, cancellation, and upgrading of the HPR are shown in Table 6. The schematic graph of parametric regressions with control variables and using first-order polynomials are shown in Figure 5. For the first implementation in March 2011, the graph presents a significant decrease in housing prices, with a drop of 592.46 ¥/m<sup>2</sup> (about 5%), and the slope of the price trend changes from positive to negative. The regression results show that except for when using the second-order polynomial in parametric model, the housing prices of other

models all show significant downward jumps. Overall, the results are relatively robust, which is consistent with prior research findings on the suppressive effect of HPR policies in eastern coastal cities including Hangzhou (Liao et al., 2018; Wu, 2019), although the price reduction is more moderate than that of Beijing (Sun et al., 2017). Regarding the cancellation of purchase restriction in August 2014 (*c* = 104), the regression result is only significant with first-order polynomial and inclusion of control variables. Figure 5 shows that there is a small drop in housing prices after the cancellation of the HPR. However, the slope of the graph changes significantly before and after this point, with the trend changing from negative to positive, which is in line with policy expectations. In the non-parametric regression model, the results are only significant when the optimal bandwidth is taken and the control variables are included, the results are not robust.

After the upgrading of the HPR in March 2017, each model showed a significant downward jump in housing prices. The results are very robust. Regarding the coefficients, in the case of optimal bandwidth including covariates, the decrease was from 1266.56 ¥/m<sup>2</sup> to 1435.94 ¥/m<sup>2</sup> (about 6–7%), while in the models excluding covariates, the maximum decrease was 1880.08 ¥/m<sup>2</sup> (about 10%). The impact is much higher than during the

Table 6. Impact of events of home purchase restriction (HPR) using parametric and non-parametric models

			First implement 2011.03		Cancellation 2014.08		Upgrade 2017.03	
Parametric regression discontinuity results	Covariates	Bandwidth	Polynomial order		Polynomial order		Polynomial order	
			1 <sup>st</sup> -order	2 <sup>nd</sup> -order	1 <sup>st</sup> -order	2 <sup>nd</sup> -order	1 <sup>st</sup> -order	2 <sup>nd</sup> -order
		Yes	1 h	-592.459**	18.004	-614.899***	-170.073	-1435.937***
	No	1 h	-889.237*	-1019.063	-103.858	212.194	-1880.083***	-64.301
Non-parametric regression discontinuity results	Covariates	Bandwidth	Kernel		Kernel		Kernel	
			Triangular (h = 21.179)	Rectangular (h = 16.635)	Triangular (h = 15.025)	Rectangular (h = 11.802)	Triangular (h = 11.379)	Rectangular (h = 8.938)
	Yes	1 h	-746.780**	-592.459*	-622.133***	-614.899***	-1266.563***	-1435.937***
	No	1 h	-1083.218**	-889.237*	-149.339	-103.858	-1623.531**	-1880.083***
	No	0.75 h	-966.479*	-975.664*	29.916	126.631	-1237.52	-1334.949
No	1.25 h	-1322.400***	-1295.487***	-365.478	-360.811	-1487.688**	-1685.935***	

Note: \*\*\*, \*\*, and \* represent significance levels at the 1%, 5%, and 10% levels, respectively.

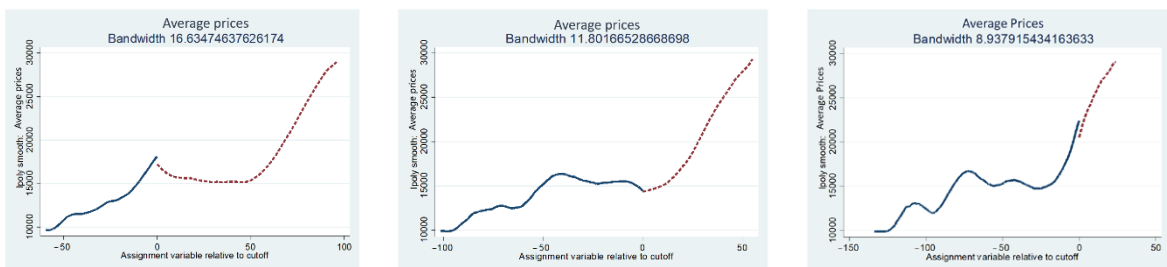


Figure 5. Impacts of HPR events (first implementation, then cancellation, and upgrading)

first implementation. Figure 5 shows that the upgrading of the HPR for local registration residents of Hangzhou had a clear transient effect on housing price reductions, but it also did not change the rising trend of housing prices, and after the implementation of the policy, the slope did not change much. In addition, this breakpoint had a relatively short impact timeframe, with a bandwidth of only 11.4 months in the triangle kernel setting.

## Conclusions

According to the definition of a major event, the major events identified in the sample period include the 2008 financial crisis, the 2016 G20 summit, and a series of HPR policies. The regression discontinuity method is used to analyze the impact of these events on housing prices in Hangzhou. The results show that various major events exert different degrees of impact on housing prices in the city.

The greatest impact on the real estate market was initiated by the 2008 financial crisis, which caused a significant decline in housing prices in Hangzhou (by about 20%). The financial crisis affected the housing market to a slightly lesser extent than the international average, at a level comparable to the decline in house prices observed in Poland and certain US cities (Trojanek, 2021; Webb et al., 2016; Reinhart & Rogoff, 2009). The short cycle of negative impact compared to other countries was mainly caused by the government bailout policy in 2009. This was followed by the holding of the G20 summit with housing prices increasing significantly (by about 10%). However, winning the right to host the conference had no significant effect, suggesting that the rising housing prices were the result of considerable infrastructure investment for the preparation of the conference, urban renewal projects, and the improvement of the city appearance, as well as the increasing attractiveness of the city and population inflow. Housing prices soared at the time when the summit was held and maintained a high growth rate for a long time. This confirms the well-known topic that G20 has boosted housing prices. It also shows the huge impact the world event has had on Hangzhou, a non-first-tier city in China. Similar to the Olympic Games and the World Expo, world events are of great significance to developing countries and serve as engines to improve city image and urban development (Lamberti et al., 2011). In preparation for such an event, a variety of resources and investments must be integrated, therefore, the legacy of the event should be considered from the start of the bid. Yamawaki et al. (2020) pointed out that different cities around the world have different concerns about the legacy of major events. The G20 Hangzhou summit is a perfect combination of considerations regarding the city's international image enhancement and urban growth direction. Both the location of the venue and the construction of the supporting transport infrastructure focused on the strategic development of urban planning, which has had a far-reaching positive impact.

These two exogenous economic and political events of international magnitude not only greatly impacted housing prices, but these impacts also lasted for more than one year. Local regulatory policies also yielded significant discontinuity, but the extents and durations of impacts were relatively small. The first implementation of the HPR policy induced a clear drop in housing prices and reversed the growth trend of housing prices, but the decline of housing prices was only about 5%. The cancellation of the HPR policy did not result in a discontinuity effect on housing prices, but significantly increased the slope of the trend of housing prices. The resumption of the HPR policy significantly reduced the transaction volume. Moreover, the upgrading of the HPR policy yielded a most apparent cooling effect on the housing prices, decreasing housing prices in Hangzhou by about 10%. However, this effect lasted only for a short time and did not change the trend of the subsequent rapid rise. The approach used in this paper allows for observing changes in house price trends because of HPR policy, rather than just estimating house price changes, which has been rarely discussed by previous studies. As stated earlier, the G20 summit had a lasting impact on the city and its housing market. As a result, the upgrading HPR policy in early 2017 could hardly reverse rising housing prices. Nevertheless, the advantage of regressions discontinuity can still capture sudden changes in transients.

It has been suggested that China's future regulatory policies will still focus on stabilizing the real estate market and it is not expected that prices will increase or decrease vastly. In this context, relevant city departments should reasonably regulate the supply and demand of the real estate market to prevent housing prices from excessively increasing. In the context of Hangzhou's booming real estate market, when the HPR policy was first proposed, it was criticized as the harshest regulation in history, and the market was affected by wait-and-see and hesitation attitudes. Considering this, the impact of the HPR policy lasted for a relatively long time. When this restriction was suspended, housing prices immediately returned to an increasing trend. When the HPR policy was launched for the second time, the market had accepted and become accustomed to the policy, the rigid demand for home purchases was further stimulated, and even strategies for coping with controls emerged. These had a more temporary impact on the market and almost did not change the growth trend. If the real estate market is to develop smoothly, other long-term mechanisms are still required to restrain housing prices. Because of the limitations imposed by the regression discontinuity method, it is impossible to separate the impacts of different events at the same time point. Therefore, when estimating the impact of the G20 summit, the upward jump in housing prices is likely underestimated because of the failure to exclude the interference of the re-start of the purchase restriction policy. Although data with higher frequency, such as weekly or daily transaction data, can be used to distance the time between events, these

data are also subject to sample size limitations or unsatisfied continuity requirements for group variables. In the future, a more detailed study of particular types of events can be conducted over a shorter time period.

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### Author contributions

Ling Zhang and Linzun Yang conceived the study and were responsible for the design and development of the data analysis. Linzun Yang and Lifei Zhu were responsible for data collection and data interpretation. Lifei Zhu wrote the first draft of the article.

### Disclosure statement

The Authors declare that they do not have any competing financial, professional, or personal interests from other parties.

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