Research on the Impact of Air Pollution on the Real Estate Market-Take Shanghai's Residential Commercial Housing Market as an Example

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Abstract. Based on urban economics, behavioural economics and western economics theory, we analysed the effects of air pollution on the real estate market through VAR model and IRF using the AQI and the residential commercial housing market data from January 1, 2015 to June 30, 2020. We found that there is intrinsic link between changes in air pollution levels and changes in real estate market. When air pollution levels increase, it will have a sustained inhibitory effect on housing price and housing turnover. The effect on housing price will last about 5 months and the effect on housing turnover will last about 2 months. After having a comparative analysis of the IRF of the average price in six jurisdictions in Shanghai we found that inhibitory effect which air pollution impact on real estate market has different forms of expression. Residents in areas with relatively poor air quality are more willing to pay for clean air and housing transactions in areas with relatively good air quality are more sensitive to air pollution.

1 Introduction

Since the Industrial Revolution, modern productions not only make people's lives convenient, but also cause the problem of resource shortage and environmental degradation to society. The same is true of China, which has also paid a huge environmental cost while becoming the world's second largest economy. According to Baidu Index, the daily queries of the word of air quality up to 27,152 searches. It can be seen that people's environmental awareness is increasing, the need for clean air is also increasingly urgent.

As the mainstay of China's urbanized process, the real estate industry plays a vital role in the development of the urban economy and national economy. From 2010 to 2018, China's real estate industry contribution rate gradually increased from 5.7% to 6.65%. The real estate market involves a wide range and strong industrial correlation, and its development has a great impact on people's living standard, local government's fiscal revenue and the industrial structure of the national economy. With the further development of urbanization, the real estate market will continue to provide strong support for the development of the national economy. However, we have to pay attention to the impact of environmental changes on the development of the real estate market. In China the people's living needs have been gradually changed from the need for material culture such as warmth and fullness to the need for a better life such as democracy and the rule of law, fairness and justice and beautiful environment. At present, citizens are not only concerned about the location of housing location, but also concerned about the surrounding air quality because of the haze problem. Some parents even plan to move to cities with good air quality for their children's health. Nowadays, people's yearning for a better life is becoming more and stronger, the requirements of the living environment gradually improve, and then air quality, as an environmental factor directly affects the healthy, is bound to have an impact on the real estate market. At the critical point of China's economic transformation, effective consumer demand is still an important factor driving economic development. We can't help but wonder if air pollution will inhibit the development of the real estate market and if the changes in air quality will lead to changes in real estate demand. If the answer is yes, is the impact of air pollution on the real estate market time-sustaining? These are issues that need to be explored in depth in this paper, and these questions do not give clear empirical evidence in existing studies.

2 Literature Review

2.1. Housing prices and the environment

The spatial structure theory of urban economics points out that because of the emissions of automobile exhaust, office ventilation system gas and living exhaust gas, urban centers would become the main source of urban environmental pollution, if we included environmental factors in the housing market (Arthur O'Sullivan, 2015)[1].Then urban center housing is less attractive and cheaper, whereas the price of the housing with better environmental quality or closer to the park will rise due to comfortable feature. Given the harmful effects of

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environmental pollution on health, people with relatively high incomes will access to better-quality housing at a price they are willing and can afford to get away from urban center, while those with relatively low incomes will be located near cities with poorer environmental quality due to transport costs (Philip McCann, 2010) [2].The theory of spatial structure is embodied in many discourses on the environment and housing market. Environmental inequality can have an impact on the real estate market, such as Ozone levels (Matthew E. Kahn et al., 2014) [3] and PM2.5 Concentration (Dengke Chen et al., 2017) [4].Environmental pollution, landscaping and other environmental factors can have an impact on residential site selection and housing prices based on artificial neural network (ANN) model to assess the real estate market (Vincenza Chiarazzort et al., 2014) [5]. Compared to noise, air pollution has no significant impact on housing location and housing prices, but globally, the sensitivity of people migrating from more polluted countries to Nantes is significant (Rémy Le Boennec et al., 2017) [6].

From the perspective of behavioral economics, actors often have a series of different levels of needs and values in mind when arranging their own behavior, and actors choose to meet the more valuable and urgent needs for them first (Ludwig von Mises, 1949) [7].Related to the transportation cost, consumers whose income level have reached a certain level, will pay more attention to the green area, air quality, natural landscape and other living environment, as well as social welfare facilities, schools and other supporting facilities (Limin Dong, 2016) [8].There is some research in the academic circles on the introduction of consumer decision-making behavior into environmental impact. For example, Raymond B. Palmquist suggested that the duration of environmental pollution does not seem to affect home sales prices in models that do not take into account the effects of the same period. However, the duration of environmental pollution can have a significant negative impact on home sales prices and booking prices when the contemporaneous was considered. The results showed that housing demand will decline and home sellers will lower their predetermined prices over time as pollution continues to occur (Raymond B. Palmquist, 1979) [9].Homebuyers are willing to pay more money for clean air., both at the community level and on an individual level. Buyers of different consumption capacity pay different attention to air quality, and buyers with stronger consumption power set a high value on the air quality of house.

From the perspective of western economics, housing has a series of characteristics, such as commuter costs, public services, comfort characteristics, etc. The equilibrium price of housing is formed by the sum of people's marginal willingness to pay for these characteristics. If we introduce environmental quality into the production process, the deterioration of environmental quality will eventually lead to a decrease in labor efficiency, which in turn will lead to changes in product prices and output. At the same time the implementation of environmental protection measures will lead to higher production costs, which in turn will lead to higher product prices. Many environmental problems are inseparable from land use, and environmental problems are likely to affect the land market and the real estate market. Hedonism pricing model, which is widely used in the influence of housing characteristic price, is to capitalize the individual value of environmental attribute improvement in housing price (Kathleen Segerson, 2001) [10].hang Bo had assessed residents' willingness to pay for air quality with the hedonic pricing approach. And he found that residents were willing to pay additional 35.91 RMB per square meter of commercial housing for PM10 decreasing and pay additional 41.65 RMB for SO2 decreasing (Zhang Bo,2017) [11].According to the coase theorem, the disclosure of air pollution information will spontaneously create environmental consolidation pressures through the market's price mechanism. The disclosure of environmental information reinforces the degree to which air quality is capitalized in housing prices, and the effect of different disclosure methods on cities is heterogenetic. In cities with a higher level of attention to PM2.5, the real estate market is more vulnerable to the disclosure of air quality information. And the impact of PM2.5 information disclosure on regional house price differences is long-term (Huiyi Zhang, 2014) [12].

2.2. Real estate consumption and the environment

There are many factors affecting real estate consumption, including the inherent attributes of house prices, as well as external attributes such as loan interest rate, land policy, residents' income level and population structure. Environmental quality, as the core of people's attention at present, will also have an impact on real estate consumption (Paul A.Bell, et al.,2009) [13].Harmful substances in the air (e.g. carbon monoxide, dust, sulfur dioxide, etc.) can cause respiratory problems, cardiovascular disease, and even cancer. Air pollution always threatens people's health. Health scientists define air pollution syndrome which is mainly manifested in headache, fatigue, insomnia, allergic irritability, depression, eye pain, back pain, impaired judgment, gastrointestinal diseases and so on (Duncan Lee, 2019) [14].The deterioration of air quality is bound to lead to poor health and rising health costs and has an impact on the income level and consumption level of the population as a whole. (Reza Bayat et al., 2019) [15]. The increase in medical care will reduce household savings assets, increase debt, crowd out food and clothing consumption, and reduce the well-being of residents (Qi Tang, 2016) [16]. The consumption expenditure of rural residents and urban residents is significantly affected by the quality of the environment, rural residents have a strong response to environmental pollution and urban residents are more sensitive to soot pollution. Environmental pollution has a direct impact on consumption through income effect and substitution effect, and indirect impact on consumption through population structure (Da Fang, 2018) [17].The influence of haze pollution on residents' consumption has strong spatial concentration and spatial dependence, and the increase of haze pollution will lead to the decline of residents' consumption level in this area.

We found that most studies focus on whether air pollution has a negative impact on housing prices, and use regression methods to quantify this negative impact. Few studies have noted how long air pollution affects house prices and how much air pollution affects the real estate market from a consumer perspective. So we analyzed the dynamic effects of air pollution on the real estate market, from both price and volume dimensions, through VAR model and IRF using the AQI and the residential commercial housing market data from January 1, 2015 to June 30, 2020. Furthermore we determined the period of sustained impact and made a horizontally comparative analysis of the six jurisdictions in Shanghai.

3 Figures and tables

3.1 Variable selection and data source

We hope to find out the impact of air pollution on the residential commercial housing market in Shanghai. The Air Quality Index (AQI), calculated by monitoring concentrations of PM10, PM2.5, SO2, NO2, CO and O3 in the air, is an unscripted index that quantitatively describes air quality and represents a significant increase in pollution as the value increases. AQI is the parameters for reporting daily air quality and describing the extent to which the air is clean or polluted and its effects on health. AQI has been under the spotlight due to its high frequency and intuition. So we use the AQI index to measure air pollution levels. We measure the residential commercial housing market from two dimensions, one is the average transaction price of residential commercial housing (represented by the word 'Price'), the other is the volume of residential commercial housing transactions including transaction area (represented by the word 'Area') and transaction unit (represented by the word 'Unit'). The China Environmental Monitoring Centre began to make air quality information available to cities throughout the country in four batches. The four starting points are January 1, 2013, October 1, 2013, January 1, 2014 and January 1, 2015. To ensure the continuity of the data, we selected the AQI Index and Residential Commercial Housing Market Data from January 1, 2015 to June 30, 2020. All the data mainly comes from Wind database, RESSET database, Shanghai air quality real-time release system, Shanghai Real Estate Exchange Centre.

3.2 Model specification

Assuming that air pollution has a significant impact on the real estate market, and we all know that the rapid expansion of the real estate market will damage the local atmospheric environment. Then air pollution and the real estate market are most likely to affect each other, that is, there exit endogeneity between the two variables. To solve this problem, the VAR model is used to investigate the impact of air pollution on the real estate market. We do not need to consider the endogeneity nature of variables when we use the VAR model in which endogeneity is explained by their lagging values. In addition, there are no exogenous variables in the VAR model which can be used to illustrate the dynamic connection between variables.

The mathematical expression of the VAR（p）model is as follows.

$$y_t = \Phi_1 y_{t-1} + \Phi_2 y_{t-2} + \cdots + \Phi_p y_{t-p} + \varepsilon_t \qquad t = 1,2,\ldots,T$$

'P' denote lag number, 'T' is sample size, ' ' is Perturbation Term.

According to our research purpose, should work on three levels:

$$y_{1t} = \begin{pmatrix} AQI_t \\ Price_t \end{pmatrix}, \quad y_{2t} = \begin{pmatrix} AQI_t \\ \mathrm{Area}_t \end{pmatrix}, \quad y_{3t} = \begin{pmatrix} AQI_t \\ \mathrm{Unit}_t \end{pmatrix}$$

So our research model is as follows.

$$y_{1t} = \Phi_1 y_{1t-1} + \Phi_2 y_{1t-2} + \cdots + \Phi_p y_{1t-p} + \varepsilon_t \qquad t = 1,2,\ldots,T \qquad (1)$$

$$y_{2t} = \Phi_1 y_{2t-1} + \Phi_2 y_{2t-2} + \cdots + \Phi_p y_{2t-p} + \varepsilon_t \qquad t = 1,2,\ldots,T \qquad (2)$$

$$y_{3t} = \Phi_1 y_{3t-1} + \Phi_2 y_{3t-2} + \cdots + \Phi_p y_{3t-p} + \varepsilon_t \qquad t = 1,2,\ldots,T \qquad (3)$$

4 Data processing and results analysis

4.1 Variable stability test

The stability of each component is a prerequisite for the traditional VAR theory, and non-stability may lead to problems such as model regression bias, t-test failure, spurious regression and spurious correlation. Therefore, we used the Augmented Dickey-Fuller, whose null hypothesis is the nonstationarity of the sequence. As can be known from the results of Table 1, the unit root test of the four variables of AQI, Price, Area, and Unit rejects the original hypothesis and accepts the alternative hypothesis, indicating that the unit root does not exist in all four variables, and they are all stationary series.

Table 1. The result of ADF text

Variable	T-statistics	Probability	Result
AQI	-20.72850	0.0000	steady
Price	-4.753255	0.0001	steady
Area	-5.487570	0.0000	steady
Unit	-6.391715	0.0000	steady

4.2 Lag order selection and Stability Tests

When we selected lags for VAR model, we should not only consider the number of lagged items, but also ensure a sufficient number of degrees of freedom. Therefore, the choice of lag order when using VAR model is directly related to the reliability of model results. Usually the method of determining the lag order is likely to be compared to the test, AIC information guidelines and SC information guidelines. Usually we use Log likelihood, AIC, SC to determine the lag order. The results of the various test methods of model (1) can be found in Table 2. Referring to the recommendations of AIC and SC, we

finally determined that lag order number of Model (1) was 7. The process of Model (2) and Model (3) are similar to Model (1), so we are no longer listed.

Table 2. Determination of the lag of model (1)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	18175.06	NA	2.65e+10	29.67	29.68	29.67
1	17479.10	1388.51	8.57e+09	28.54	28.57	28.55
2	-17451.0	55.8701	8.24e+09	28.50	28.54	28.52
3	17411.08	79.4736	7.77e+09	28.44	28.50	28.47
4	17390.81	40.2563	7.56e+09	28.42	28.49	28.45
5	17380.52	20.3935	7.49e+09	28.41	28.50	28.44
6	17356.66	47.2116	7.25e+09	28.37	28.48	28.42
7	17335.54	41.7143*	7.05e+09*	28.35*	28.47*	28.39*
8	17333.31	4.39319	7.07e+09	28.35	28.49	28.40

In order to ensure the reliability of the following IRF results and the validity of the analysis, we judged the stability of the VAR model by the distribution of feature values. We found that all feature roots are within the unit circle indicating that three VAR systems are stable. There is a feature root that is very close to the boundary of the unit circle in Model (1), which means that some shocks have a strong continuity.

4.3 Granger causality test

Granger causality test is often used to determine whether there is a causal relationship between variables, and its null hypothesis is that the past value of the independent variable is not helpful in predicting the future value of the cause variable. So if the test results show that the null hypothesis was rejected, it means that the independent variable is granger of the cause variable. Therefore, we inspect whether there is a Granger causal relationship between air pollution and the real estate market based on the Granger causal test. As can be seen from the results of Table 3, at a 15% level of significance, most tests reject the null hypothesis. For example, in model (1), the average house price variable rejects the null hypothesis at the 15% significant level, and the air pollution variable rejects the null hypothesis at a 10% significant level. It shows that there is a two-way Granger causality connection between air pollution and average residential prices. This result laterally verifies that the two variables in the model (1) are endogenous-variables, and verifies the validity of the establishment of the VAR model.

Table 3. The result of ADF text

	Null Hypothesis	F-statistics	Probability
Model（1）	PRICE does not Granger Cause AQI	2.25835	0.1331
	AQI does not Granger Cause PRICE	3.79614	0.0516
Model（2）	AREA does not Granger Cause AQI	1.52634	0.1157
	AQI does not Granger Cause AREA	1.50262	0.1241
Model（3）	UNIT does not Granger Cause AQI	8.81680	0.0030
	AQI does not Granger Cause UNIT	0.87612	0.3494

4.4 Impulse Response Function

The impulse response function (IRF) can be used to analysis the dynamic impact relationship between variables in the VAR system and reveal whether changes in a given variable have a positive or negative effect on other variables in the system. And it could keep track the variable changes in the future moments, could reflect the dynamic changes between variables in the VAR system. Therefore, we use the IRF to study the dynamic impact of air pollution on the real estate market. The results of IRF are shown in Figure 1 to 4. In order to better observe the pulse response trend, we set different impact periods for different variables.

4.4.1 Results analysis of real estate market in shanghai

As can be learned from Fig 1, when the impact of a standard deviation is given to AQI in the current period, Price's response achieves the greatest negative impact in the 6th period after fluctuations up and down during the first 4 periods. And then the effect begins to decay

gradually, until after 150 phases gradually tend to zero. However, in this process, its impact is always negative, so it can be known that air pollution has a dampening effect on the average price of housing. This conclusion is consistent with the spatial structure theory of urban economics and the conclusions of most scholars, while providing empirical evidence to support the previous hypothesis in this paper. Air pollution has a persistent reverse effect on house prices and lasts for about 5 months.

As we can see from Figure 2, the positive impact of AQI can have a negative impact on Area, and in the 4th phase the negative impact reached a maximum of 901, then shock weakened as time goes on. Eventually, the negative effect disappeared after 59 days. The result of Figure 3 shows that Unit's response to AQI, also experienced the negative impact of attenuated volatility and disappeared around the 55th phase, is very similar to Area's. Combine the above two results, we could say that air pollution will have a reverse impact on the turnover of residential commercial housing. In other words, increasing air pollution may leads to a drop in volume of real estate market, but the duration is slightly shorter than the impact on house prices and this reverse impact will last about 55 to 60 days.

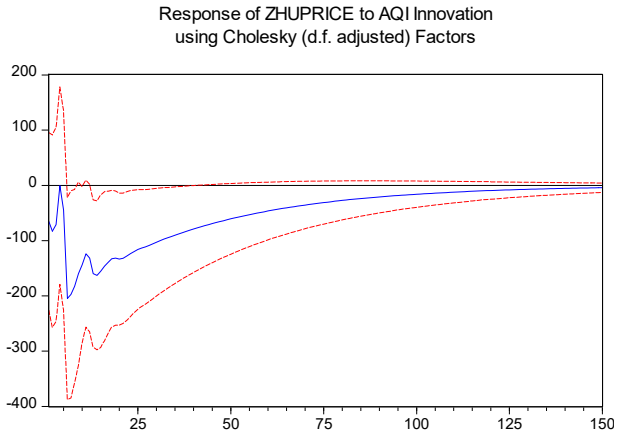


Fig1. Response of Price to AQI innovation

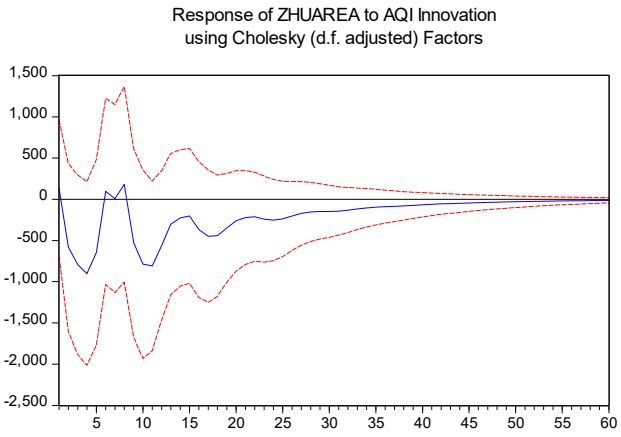


Fig2. Response of Area to AQI innovation.

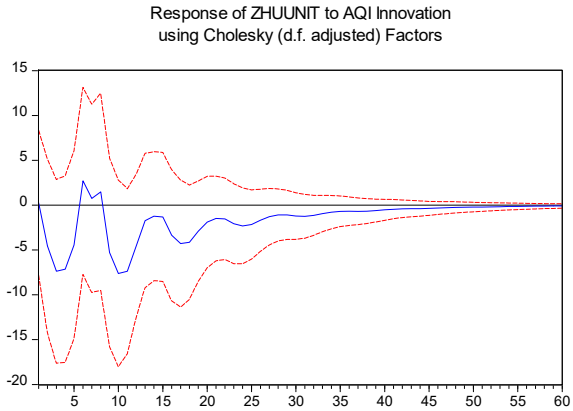
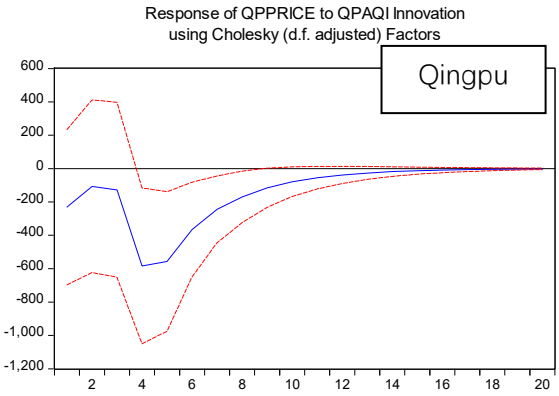


Fig3. Response of Unit to AQI innovation.

4.4.2 Comparative analysis of the real estate market of Shanghai urban area

According to the real estate market data of various regions of Shanghai, as well as the data of the air pollution monitoring site in Shanghai, we selected six territories to do further comparative analysis. We calculated the proportion of days of mild pollution and above in each district during the sample period, and found that the air quality conditions in the six jurisdictions from good to bad were Pudong New District, Hongkou, Xuhui, Huangpu, Yangpu, Qingpu District.

The response function result of Price caused by AQI shock in six jurisdictions is showed in figure 4, which is consistent with the previous analysis that AQI may have a continuously negative impact on home Price. By further comparison, we believe that AQI's negative impact on Price is stronger and more pronounced as air pollution levels increase, and the persistent period of AQI's negative impact on Price continues to be lengthening as pollution levels decrease. This phenomenon may be due to the strong demand for clean air among urban residents with relatively poor air quality for clean air housing. In urban areas where air quality is relatively good, residents pay more attention to air quality indices when they go out, so housing transaction times are more sensitive to changes in air pollution.



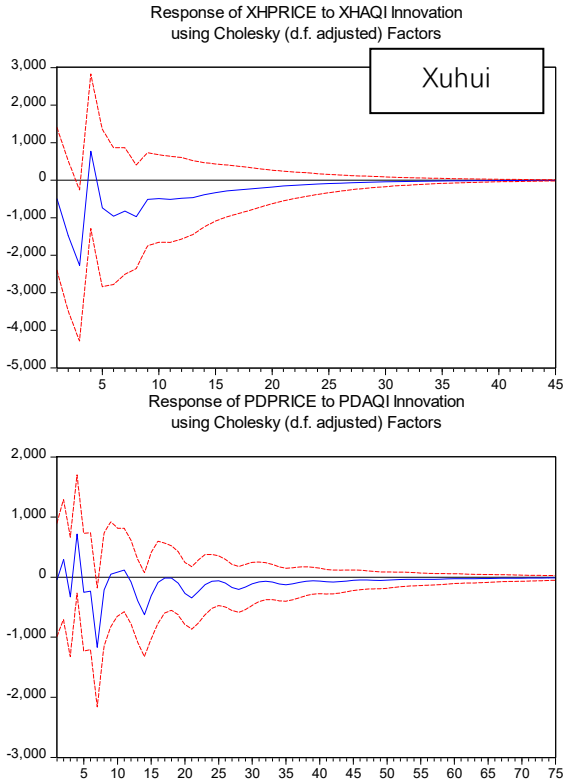


Fig4. Response of price to AQI innovation of territories in Shanghai.

5 Conclusion and Policy Implications

We analysed the impact of air pollution on the real estate market based on VAR model and impulse response function, using the air quality index and residential commercial housing market data from January 1, 2015 to June 30, 2020 in Shanghai. Finally our findings are as follows.

Firstly, based on results of Granger causality test, we could determine that AQI index has a two-way Granger causal relationship with the average house transaction price and the transaction area, and a single Granger causal relationship with the housing transaction area. It suggests that there is an internal relation between changes in air pollution levels and changes in the real estate market. Combined with the results of the model robustness checks, the validity of the VAR model is explained. Based on the results of the study, we believe that the public demand for high-quality air has developed a clear willingness to pay with the increasing awareness of the environment, the increase in air pollution significantly increased its capitalization in housing prices is one of the examples. The capitalization of air quality in the real estate market means that local governments are committed to air pollution for economic development reasons, even if they do not directly use improving air quality as an indicator.

Secondly, according to the impulse response function of Shanghai residential real estate market, increased levels of air pollution can have a sustained dampening effect on house prices and volume, the impact on housing prices will last about 5 months, the impact on housing volume will last about 2 months. On the basis of this conclusion, we can infer that, with the strengthening of inhabitants' environmental awareness and their yearning for a better life, the improvement of air quality will enhance the potential value of Shanghai's spare houses and promote the further development of Shanghai's urban economy. Due to the liquidity of the atmosphere, unilateral administration of air pollution was proved futile. Regional government should conduct cooperative respond and multilateral administration to control air pollution to a certain extent, to avoid the impact of poor air quality on the real estate market and regional economic development.

Finally, by comparing the impulse response function of the average residential price on air pollution impact in six jurisdictions in Shanghai, we found that the negative impact of relatively poor air quality is significant, and inhabitants are more willing to pay for clean air, and negative effects in areas with relatively good air quality persist for longer periods of time, and housing transactions are more sensitive to air pollution. From this result, we could consider that insist on the city's policy at the same time appropriate implementation of the district policy when implementing real estate regulation and control policies. Based on the preference of the residents of the jurisdiction to pay for housing, the differentiated policy could be formulated, and the goal of controlling the demand for investment housing is realized from the micro level. Besides, the government should also strengthen macro-control efforts to avoid the sustained inflation prices of the real estate market due to the existence of air quality capitalization.

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