Hindawi
Indoor Air
Volume 2023, Article ID 1338261, 7 pages
https://doi.org/10.1155/2023/1338261

*Research Article*

# Unleashing the Casual Impact of House Prices on Air Quality: Evidence from Chinese Cities

**Bing Zeng**[1], **Shah Fahad**[2,3], **Gang Wang**[1], **Abdelmohsen A. Nassani**[4] and **Rima H. Binsaeed**[4]

[1]*School of Economics, Anhui University of Finance and Economics, Bengbu 233030, China*
[2]*School of Management, Hainan University, Haikou 570228, China*
[3]*School of Economics and Management, Leshan Normal University, Leshan 614000, China*
[4]*Department of Management, College of Business Administration, King Saud University, P.O. Box 71115, Riyadh 11587, Saudi Arabia*

Correspondence should be addressed to Shah Fahad; shah.fahad@xjtu.edu.cn and Gang Wang; w_gangg@gmail.com

Received 14 October 2022; Revised 3 May 2023; Accepted 5 June 2023; Published 30 August 2023

Academic Editor: Geun Young Yun



With the rapid development of the real estate industry in China, urban air quality is inevitably affected. By using data of Chinese cities located in the Yangtze River Delta from 2009 to 2018, this paper is aim at examining the casual impact of house prices on air quality. By considering the endogenous problems, in this study, first, the birth rate of the previous six years and the area of state-owned land supply per capita in the previous year are taken as instrumental variables of house price. Second, the two-stage least squares method is used to assess the causal impact of house price on air quality. The findings of this study show that there is no significant relationship between urban house prices and air quality, and these results are obtained without considering the endogenous problem. While, after considering the endogenous problem, urban house prices showed a significant negative effect on overall air quality, especially for low administrative level cities. The increase in house prices has hindered the improvement of air quality mainly through the blind-scale expansion of real estate development investments and the inhibitory effect of innovation.

## 1. Introduction

Since the reform of housing commercialization in 1998 in China, the real estate industry has become a pillar industry in the development of the Chinese national economy, which has caused housing prices to rise. The continuous rise of housing prices has brought about high profits, in turn, that will further accelerate the development of the real estate industry. On the one hand, the continuous development of the real estate industry will promote the emission of dust, sulphur, and nitrogen oxide in the enterprises that produced steel and building materials during production processes; meanwhile, dust and other air pollution may be generated during the construction process of the program about real estate. On the other hand, high profits will lead to the flow of economic factors to the real estate industry in pursuit of profits, thus restricting technological innovation and green production. It is of certain practical significance to explore the causal impact of house price on air quality.

Housing prices and air quality are two topics closely related to people's lives, and they are also popular topics among scholars. For research of housing prices, scholars focus mainly on population mobility [1], household consumption [2], enterprise development [3], and education development [4]. At the same level, the research field is relatively broad, and the results are also relatively richer. In terms of air quality research, it emphasizes economic factors [5], urban factors [6], crime factors [7], migration factors [8], and other factors to explore the causal relationship of air quality from a multidimensional perspective. Research on the relationship between housing prices and air quality focuses more on the impact of air quality on housing prices. Zou [9] and Ou et al. [10] used panel data from cities at the prefecture level of China to examine the effects of pollution

on the prices of urban housing in China. Lang [11] examines the time path of prices and preference-based classification in response to air quality changes caused by differential regulatory pressure from the 1990 Clean Air Act Amendments. Surprisingly, very few studies are available to analyze the causal impact of housing prices on air quality. High housing prices will not only lead to blind expansion of the real estate industry but also distort investment and weaken the ability of companies to innovate green technology, thus affecting the governance of the air environment. Therefore, the scientific measure of the impact of housing prices on air quality development will help deepen the understanding of the problems related to housing prices, scientifically judge the real impact of real estate on green development in China, which is of great practical significance for further adjustment of industrial structure and innovation-driven development, as well as for the full play of the positive role of the real estate industry in high-quality economic development, and provide new evidence for the increase in prices on the negative effect of urban air quality development, to be more comprehensive and targeted for relevant departments to provide reference.

## 2. Empirical Design

*2.1. Causal Identification Strategy.* This paper mainly considers the unidirectional impact of housing prices on the development of air quality, focusing on the causal identification of the impact of housing prices on air quality. The benchmark measurement model is as follows:

$$\mathrm{AQ}_{it} = \beta_0 + \beta_1 \mathrm{HP}_{it} + \delta X + \lambda_i + \eta_t + \varepsilon_{it}. \quad (1)$$

AQ is the explained variable: air quality; HP is the core explanatory variable: house price; $X$ is the corresponding control variable; $i$ is the city, and $t$ is the year; $\lambda_i$ is the regional fixed effect, controlling the influence of invisible factors that do not change with time; $\eta_t$ is the annual fixed effect, controlling the impact of the annual macroeconomic policy; $\varepsilon_{it}$ is the random disturbance term. At this time, if the least squares method is used directly to estimate the relationship between the two, it is easy to produce estimation bias, resulting in misreading of the development relationship of air quality. Because the model may ignore the reverse causal relationship between housing prices and urban air quality, then, it will contribute to the endogenous problem of housing price. On the one hand, people will choose housing according to air quality, affecting the supply and demand of the housing market and changes in housing prices. On the other hand, local governments can take action to address the negative impact of housing prices on air quality that is "correct mistakes" behavior. They will make reasonable adjustments to the real estate development, thus affecting the change of the housing price. In addition, some invisible missing variables that change over time also produce endogenous problems, such as people's expectations of housing prices, which will push them up when they expect prices to rise, whereas expectations of rising prices also affect air quality. These endogenous problems will affect the causal inference of this paper. Only by correctly separating the causal effect of housing prices on air quality can we scientifically evaluate and make a correct judgment. If the method is not used properly, the evaluation results will not only mistake the impact of housing prices but will also be misleading. Therefore, how to control and weaken the above reverse causality and missing variable factors that may bring about endogenous problems is the key to scientifically capturing the impact of housing prices on the development of air quality. To reduce estimated bias as much as possible, this paper uses the instrumental variable method to overcome the endogenous problem. Scientific selection of instrumental variables should usually meet two main conditions: one must be associated with endogenous explanatory variables, and the other is that instrumental variables cannot be related to the error term in the regression model [12]. The regional birth rate in the previous six years (BR) was used as one of the instrumental variables. Compulsory education resources have a strong capitalization effect on China's urban housing prices [13]. The birth rate in a region is usually an exogenous factor, and the higher the birth rate in a region not only will it increase the size of the local population, but also, these births will receive compulsory education in the future, while higher education scale and population size will increase housing prices. According to the "compulsory education law" in China, all children over the age of six, regardless of gender, nationality, or race, should enter school to accept the compulsory education of prescribed fixed number of years. Therefore, the regional birth rate in the previous six years (BR) is used as an instrumental variable in this paper. Furthermore, land for real estate development in China is acquired in the form of land transfer, while the land use and transfer of various cities must be subject to strict government control. The supply of land in real estate is a strong exogenous government policy variable [14]. Therefore, this article selects the per capita state-owned land supply and transfer area in the previous year (LS) as the instrumental variable of the housing price. The reason for selecting the previous year is that it takes some time from land acquisition to development. Moreover, the regional birth rate in the previous six years (BR) and the per capita state-owned land supply and transfer area in the previous year (LS) served as historical variables, and they have little relationship with the current error term. In conclusion, both theoretically meet the characteristic requirements of the instrumental variables. After finding the instrumental variables, the regression was performed using a two-stage least squares method. In the first stage, the endogenous variable, the housing price, is regressed to the instrumental variables and other control variables to obtain the fitted value of the housing price, which reflects the exogenous part of the separated housing price variables. The model is as follows:

$$\mathrm{HP}_{it} = \alpha_0 + \theta_1 \mathrm{BR}_{it} + \theta_2 \mathrm{LS}_{it} + \delta X + \lambda_i + \eta_t + \varepsilon_{it}. \quad (2)$$

In the second stage, the house price adjustment values are brought into the following regression model to eliminate

bias and obtain consistent estimates. The coefficient $\beta_1$ is the reference to scientifically reflect the impact of housing prices on air quality:

$$AQ_{it} = \beta_0 + \beta_1 \widehat{HP}_{it} + \delta X + \lambda_i + \eta_t + \varepsilon_{it}. \quad (3)$$

*2.2. Variables and Data*

*2.2.1. The Core-Explained Variable: Air Quality (AQ).* In this paper, the average annual concentration of PM2.5 is used to characterize air quality. PM2.5 is not only an important indicator of the national standard of ambient air quality in China but also a widely used measure indicator in relevant studies [15]. The higher the PM2.5, the worse the air quality.

*2.2.2. The Core Explanatory Variable: The Price of Urban Housing (HP).* The housing price data of various cities is collected with the help of the web crawler technology on the website http://www.fang.com and http://www.anjuke.com and other real estate transaction information platforms in China.

*2.2.3. Control Variables.* To control the influence of other factors on model estimation, this paper also controls some other variables that may affect urban air quality. Referring to existing research, select the current unit output value of three waste pollution intensity logarithms, college students, gross regional product per capita, the proportion of the secondary industry, and the actual utilization of foreign investment, in turn, as environmental regulation (ER), education development (Edu), economic development (ED), industrialization (IND), foreign investment development (FID) five levels of control variables.

*2.2.4. Data Source and Description.* The study object is conducted in 41 cities in the Yangtze River Delta region, spanning from 2009 to 2018. The data is obtained from the corresponding years of the China Regional Economic Statistical Yearbook, China Urban Statistical Yearbook, China Environmental Statistical Yearbook, China Land and Resources Statistical Yearbook, and the statistical yearbook of provinces and cities. The PM2.5 data were obtained from the atmospheric composition analysis organization, which provides grid data, which integrates remote sensing monitoring, model simulation, and site measurement, and is characterized by comparability and objectivity. With ArcGIS10.2 software, it masks the vector map of the city at the prefecture level of the Yangtze River Delta and extracts the data of the average concentration value through partition statistical tools in milligrams/cubic meter. They were log-normalized except for the IND and BR variables. Missing data was supplemented by the interpolation method.

## 3. Results and Discussion

According to the empirical design, panel data from 41 cities in the Yangtze River Delta region from 2009 to 2018 were used for the first time, and benchmark regression analysis was conducted without instrumental variables to test the comprehensive impact of urban housing prices on air quality. Considering that the goodness of the double-fixed-effect model is better than that of other models, the corresponding test also supports the fixed effect. And both cross-section factors and time series changes are considered in the double-fixed-effect model. Therefore, the double-fixed-effect panel model is used for analyzing problems in this paper (double-fixed-effect treatment is used later), and the corresponding regression results are reported in Table 1.

The results of the benchmark regression show that the impact of the prices of urban housing on air quality is insignificant no matter how the control variables are adjusted. At the same time, considering the effect of the environmental Kuznets curve between economic development and environmental development, or the square term of economic development, it still fails to significantly show the impact of housing prices on air quality. This may be the result of the bidirectional causality between urban housing prices and air quality: urban housing prices take a significant inhibitory effect on air quality, while local governments will regulate housing prices to some extent. And the better the air quality in a city, the more housing demand will be, which will affect housing prices. Furthermore, missing variables also cause nonsignificant regression coefficients. This paper follows the idea of empirical design, further using BR and LS as instrumental variables and using the two-stage least squares method to overcome these endogenous problems to some extent. Relevant results are reported as shown in Table 2.

The use of instrumental variables is the premise of endogenous explanatory variables in the model. Endogenous housing price problems caused by the two-way causality between housing prices and air quality and the omission variables should also be tested from the perspective of mathematics. According to the Hausman test, the original hypothesis in which all explanatory variables are exogenous is rejected at the 1% significance level. It means that the benchmark model has some endogenous problems, so the instrumental variable method can be adopted. The rationality of the instrumental variables needs to be further tested to ensure that the instrumental variable model can be adopted. From the perspective of weak instrumental variable test, in the first stage, the birth rate and land were significantly associated with house prices, the $p$ value is less than 0.01, and the $F$ value is 184.536, much larger than the corresponding critical value of 11.59; there is no weak instrumental variable; the Sargan value is 0.030; the corresponding $p$ value is 0.8628, accepting the original hypothesis that all instrumental variables are exogenous, namely, the two instrumental variables selected here are not related with the disturbance item. Together, these tests all point to the plausibility of the instrumental variables selected in this paper. Through the instrumental variable method, the regression results further show that the regression coefficient of 0.1485, the significance level reaching 0.05, is positive for the cities of the Yangtze River Delta in the PM2.5 index. With urban housing prices increasing by 1%, the PM2.5 index increases by 0.1485%. The worse the air quality, the current prices of urban housing cannot improve urban air quality. Therefore, urban housing prices must be adjusted urgently. Possible reasons are that rising housing prices tend to stimulate excessive investment in real estate development to promote

Table 1: Benchmark regression.

| Variables | Benchmark regression I | Benchmark regression II | Benchmark regression III |
|---|---|---|---|
| HP | -0.0015 (0.0297) | -0.0394 (0.0377) | -0.0621 (0.0439) |
| ED | | -0.0272 (0.0309) | 1.6956*** (0.3750) |
| ED * ED | | | -0.0747*** (0.0162) |
| ER | | -0.1293*** (0.0193) | -.1441*** (0.0190) |
| EDU | | -0.2559*** (0.0732) | -0.2004*** (0.0722) |
| IND | | -0.2515 (0.5068) | -1.9992*** (0.6219) |
| FID | | 0.0259 (0.0175) | 0.0061 (0.0175) |
| Constant | 3.9164*** (0.2634) | 7.0697*** (0.5328) | -0.8046 (1.7855) |
| Time-fixed effect | Yes | Yes | Yes |
| Area-fixed effect | Yes | Yes | Yes |
| $R^2$ | 0.3822 | 0.1954 | 0.1034 |

Note: standard error in parentheses; *, **, and *** are successively 10%, 5%, and 1% significance levels; the following table is the same.

Table 2: Two-stage least squares regression.

| Variables | Stage I | | Stage II |
|---|---|---|---|
| HP | | | 0.1485** (0.0666) |
| BR | 0.4841*** (0.0456) | | |
| LS | 0.2199*** (0.0582) | | |
| Control variable | Yes | | Yes |
| Time-fixed effect | Yes | | Yes |
| Area-fixed effect | Yes | | Yes |
| The Hausman value | | 52.36*** | |
| $F$ value | | 184.536*** | |
| Sargan value | | 0.030 | |

Note: standard error in parentheses; *, **, and *** are successively 10%, 5%, and 1% significance levels; the following table is the same.

the rapid expansion of the area and population of the urban infrastructure, aggravating the consumption of various resources and polluting production. Furthermore, excessive profits induced by rising housing prices will cause economic factors to flow into the real estate industry for profit, leading to negative effects such as innovative brain drain and cross-industry arbitrage, thus restricting industrial enterprises' innovation, hindering industrial upgrading, and improving urban air quality.

## 4. Further Analysis

*4.1. Heterogeneity Analysis of Administrative Levels.* Cities with a high administrative level have natural advantages in authority setting, resource allocation, and institutional arrangement in China [16]. To judge the impact of housing prices on the air quality of cities with different administrative levels, this document further divides the total sample into high administrative levels and general administrative levels. The Yangtze River Delta region varies greatly in urban administrative levels, covering municipalities directly under the central government, subprovincial cities, general provincial capitals, and general prefecture-level cities. Taking into account the importance of the administrative level and the government station, in this document, municipalities directly under the central government (Shanghai), the deputy provincial city (Nanjing, Hangzhou, and Ningbo), and the general provincial capital city (Hefei) as a high administrative level are considered. In addition, some cities have the authority to formulate local laws and regulations whose leaders are members of the Standing Committee of the Provincial Party Committee, such as Wuxi, Xuzhou, and Suzhou. Therefore, they are also classified as a high administrative level. Other cities at the prefecture level are the cities at the general administrative level. The instrumental variable method is used to estimate and compare the regression of the two subsamples, and the results are shown in Table 3.

In the results of the sample regression, the Hausman test rejects the original hypothesis that all explanatory variables are exogenous. The $F$ value of weak instrumental variables and the $p$ value of Sargan's overidentification test verify the correlation and exogeneity of instrumental variables. Therefore, the instrumental variable method for urban sample regression at the administrative level has scientific rationality. The housing price of high administrative level cities is relatively higher than that of general administrative level cities,

Table 3: Administrative grade city sample regression.

| Variables | High administrative level city | | General administrative grade city | |
|---|---|---|---|---|
| | Stage I | Stage II | Stage I | Stage II |
| HP | | 0.0216 (0.0895) | | 0.3257*** (0.0288) |
| BR | 0.7168*** (0.0949) | | 0.6855*** (0.0464) | |
| LS | 0.1440** (0.0699) | | 0.1282*** (0.0209) | |
| Control variable | Yes | Yes | Yes | Yes |
| Time-fixed effect | Yes | Yes | Yes | Yes |
| Area-fixed effect | Yes | Yes | Yes | Yes |
| Hausman value | 10.75* | | 40.40*** | |
| *F* value | 28.494*** | | 109.929*** | |
| Sargan value | 2.303 | | 0.438 | |

Note: standard error in parentheses; *, **, and *** are successively 10%, 5%, and 1% significance levels; the following table is the same.

so the air quality of high administrative level cities should be lower than that of general administrative level cities in the normal sense. However, by comparing the regression of the two samples, we can find that the coefficient of house prices for the core explanatory variable is significantly positive in the regression of the general administrative level cities; therefore, for the general administrative level of cities, housing prices play a significant inhibitory effect on air quality. From the regression results of high administrative level cities, the coefficient of house prices is positive but not significant, which shows that housing price has not been able to play a significant role in the development of air quality in high administrative level cities. The environmental governance of general administrative level city requirements and the intensity of housing price regulation is weaker than that of high administrative level cities. Housing price rise is easy to cause "land to attract capital" and land finance, which will promote low quality expansion of the real estate and lead to the low-level expansion of resource-consuming and environmental-polluting industries. It is prone to the phenomenon of bottom competition at the expense of the environment, thus strengthening the inhibitory effect of housing prices on air quality. High administrative level cities have a good development foundation and economic development advantages in the development of real estate, which can not only offset environmental pollution, innovation inhibition, and other negative effects but can also shift consume resources and environmental pollution production to general administrative level cities, more driving the general administrative level cities of high-energy consumption and high-pollution industries. Furthermore, in the case of housing prices rising together, high administrative level cities of diversified preference utilities and employment space, etc. make labor, especially high technology talent willing to endure high housing prices and flow to high administrative cities, leading to green innovation development of general administrative level cities, which weaken the technical support of air environment management.

*4.2. Effect Mechanism Analysis.* Further test the impact mechanism of housing prices on air quality. According to the above analysis, there are two reasons why housing prices affect air quality. First, the price of housing changes the investment scale or intensity of real estate development investment, which causes the development of the corresponding high-pollution industries, suppressing the improvement of air quality. Second, the excessive profits induced by housing prices will lead to the flow of economic factors to the real estate industry, thus restricting the technological innovation and green production of enterprises, which is not conducive to environmental governance. Therefore, this paper attempts to examine the mechanism of influence of these two aspects. As for the influence mechanism of the real estate development investment scale, the proportion of municipal real estate development investment in fixed asset investment is adopted to measure the investment scale of real estate development investment and selected population density (PD), resident urbanization rate (UR), and other control variables. Influencing the mechanism on the aspect of innovation, we use invention patent authorization to measure urban innovation, patent authorization tree as the output of innovation that reflects the final effect of innovation activities, and the data has the characteristics of comparability and easy access and is the relevant research widely used at home and abroad. At the same time, regional financial science and technology expenditure (TE) was selected. The corresponding regression results are shown in Table 4.

From the impact of housing prices on the intensity of real estate development and investment, whether or not the control variable is applied, it has significant promotion effects. This also means that the current housing price increase is easy to lead the real estate to pursuit of construction scale and speed blindly and lack of enthusiasm for city constructions about green and environmental protection. Real estate development investment will not only produce dust pollution in the construction process, and real estate development can also promote the development of building materials, decoration materials, furniture, home furnishing, and other high-energy consumption, high-pollution products of upstream and downstream enterprises. These companies emit dust, sulphur, and nitrogen oxides in the production process, which hinders the improvement of urban air quality. From the perspective of the impact of housing price on urban

Table 4: Mechanism regression analysis.

| Variables | Investment in real estate development | | Urban innovation and development | |
|---|---|---|---|---|
| HP | 1.0223*** (0.0392) | 0.4695*** (0.0434) | -1.9914*** (0.1043) | -0.3695*** (0.1198) |
| PD | | 0.4548*** (0.0514) | | |
| UR | | 1.2358** (0.5047) | | |
| IND | | 1.8556** (0.8761) | | -1.1480 (1.6106) |
| ED | | 0.0066 (0.0236) | | 0.6862*** (0.0983) |
| FID | | 0.0689** (0.0321) | | 0.1928*** (0.0558) |
| ER | | | | 0.2685 (0.1688) |
| EDU | | | | 0.5409** (0.2367) |
| TE | | | | 0.5462*** (0.0652) |
| Time-fixed effect | Yes | Yes | Yes | Yes |
| Area-fixed effect | Yes | Yes | Yes | Yes |
| $R^2$ | 0.4572 | 0.5881 | 0.5264 | 0.7944 |

Note: standard error in parentheses; *, **, and *** are successively 10%, 5%, and 1% significance levels; the following table is the same.

innovation and development, whether the control variables are applied or not, it has a significant inhibitory effect, further demonstrating that the high price of housing is not conducive to urban innovation. The high profit margin of real estate-related industries caused by rising housing prices causes the manufacturing industry with innovative ability to turn to the real estate industry in pursuit of a high remuneration rate. Amini et al. [17] conducted in Iran and reported that an increase in the outdoor nitrogen dioxide concentration leads to a decline in prices (housing), which contradicts our findings. Enterprises will invest more resources in the real estate market, which will squeeze out the effect and generate the "mismatch effect" of capital from real to virtual. At the same time, rising housing prices increase the cost of living and production, increase the "spatial stickiness" of population migration, and generate the "crowding out effect" of innovative talents and the "blocking effect" of entrepreneurial vitality [18]. The inhibitory effect of housing price on innovation ultimately weakens the effect of air pollution control and has a negative impact on urban air quality. The findings of our study are in line with Chay and Greenstone [19], who reported that the marginal benefits of the reduction of total suspended particulates are lower in communes, resulting in high pollution. In addition, Bento et al. [20] reported that according to the appreciation of house prices, low-income residents receive annual benefits, compared to high-income residents. Our findings are in contradiction with the study by Zhang et al. [21], who conducted a study in the Huai River area and reported that air quality substantially affects house prices. The findings of our study further support the study of Amini et al. [17], who reported that an increase in outdoor pollution leads to a decline in house prices. A study by Liu et al. [22] showed that the average reduction in PM10 is related to the increase in house prices, significantly supporting the findings of this study. In general, air pollution directly impacts the well-being of households [23], while the price of housing continues to increase [24]; air quality problems and even the ecological impact caused by it cannot be ignored, which needs timely solution [25, 26].

## 5. Conclusion and Policy Implications

Real estate development and environmental protection itself are a contradiction of the unity of opposites. While the price of housing continues to rise, air quality problems and even the ecological impact caused by it cannot be ignored. Different from the traditional influence of air quality on housing prices, this paper tries to study the causal effect of housing prices on air quality and selects 2009-2018 Yangtze River Delta urban samples as empirical evidence and considers the urban housing prices and air quality causality endogenous problem selecting the birth rate in the previous 6 years and the state-owned land supply area in the previous as instrumental variables of housing price, using the two least squares to test the relationship between urban housing prices and air quality. Furthermore, we test the influence of administrative level heterogeneity and the influence mechanism. The study found that the comprehensive impact of urban housing prices in the Yangtze River Delta region on air quality is negative, and for every 1% increase in city house prices, the PM2.5 index will increase by 0.1485%. The correlation tests also verify that the selected instrumental variables have rationality and further verify the robustness of this conclusion. Housing price in general administrative level cities plays a significant role in inhibiting air quality, but housing prices in high administrative level cities have not played a significant role in inhibiting air quality development. This difference in impact may be related to differences in environmental governance requirements, institutional arrangements, and diversification preferences in cities with different administrative levels. In addition, the rise in housing prices is mainly hindered by the blind-scale expansion of real estate development investment and the inhibitory effect of innovation. In view of the results of the analysis and the conclusions of this document, the regions should fully realize the inhibitory effect of rising housing prices on air quality and reasonably control the price of housing. In real estate development and construction, the coordination between construction and environment is

emphasized, and scientific and technological innovation is strengthened. We will establish a sound environmental monitoring system and pay attention to the assessment of environmental pollution loss risk in the real estate value assessment. We should pay attention to the urban-level heterogeneity effect of house prices and avoid the zero-sum game of air quality development between cities.

## Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

## Conflicts of Interest

The authors declare that they have no conflicts of interest.

## Acknowledgments

This work is supported by the Researchers Supporting Project number (RSP2023R87), King Saud University, Riyadh, Saudi Arabia, and the Natural Science Foundation of China (Grant No. 72163010).

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