Public and Private Provision of Clean Air:

Evidence from Housing Prices and Air Quality in China

Lin Zhang[*]and Huanhuan Zheng[†]

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Abstract

We explore the dynamic interaction between housing prices and air quality in a growing economy with changing preferences using panel vector autoregression. Using Chinese data, we document robust evidence that better air quality is rewarded by the market with higher housing prices and that faster housing price growth in turn contributes to further air quality improvements. The positive impact of housing price growth on air quality is stronger for more developed areas such as eastern China, first-tier cities, and housing markets that grow faster than the median. From a time-series perspective, the contribution of housing prices to air quality improvements has been more pronounced since the Global Financial Crisis, when landscape architecture and energy efficiency gained prominence in real estate development. Further analysis reveals that higher housing price growth improves air quality by motivating public and private investment in environmental protection and enhancement that subsequently leads to better air quality.

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[*] School of Energy and Environment and Department of Public Policy, City University of Hong Kong, Hong Kong. Email: l.zhang@cityu.edu.hk.

[†] Lee Kuan Yew School of Public Policy, National University of Singapore, Singapore. E-mail: sppzhen@nus.edu.sg.

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1 Introduction

Clean air benefits public health and happiness (Levinson, 2012). With increasing environmental literacy, more and more efforts and resources have been dedicated to improving air quality. How to effectively promote provision of such an important public good is critical for most countries, especially those struggling with air pollution. The existing literature focuses on the role of government in providing public goods, but often ignores the budget constraints. What is left unaddressed in the literature is whether the increasing market value of clean air may provide business opportunities that motivate private provision of this type of public good.

The rapid industrialization of China has been accompanied by rising housing prices and fast-deteriorating air quality, which provides an excellent opportunity to study both public and private provision of public goods. The housing price boom has attracted substantial capital to the real estate market and generated voluminous transactions, which adds sizable fiscal revenues to the government's balance sheets. With fewer budgetary constraints, government can afford to invest more in environment protection and green space that will help to improve the air quality.

Additionally, the housing boom offers a significant premium for quality housing that motivates real estate developers to provide public goods. Intuitively, individuals who value clean air are willing to pay a premium for houses located in neighbourhoods with good air quality. Property developers can thus increase profits by investing more in greenspace and clean energy, which ultimately improve the air quality, as long as the additional investment is less than the total premium paid by home buyers. If clean air is universally available, consumers will have no incentive to pay a premium for it. If housing prices are stable or even falling, the marginal benefit for additional investment in improving air quality is relatively low. In either case, property developers are unlikely to provide clean air privately. In China, clean air becomes more and more scarce, especially in big cities, while the demand for it escalates as individuals become increasingly aware of the harm of air pollution, which raises the market value of clean air substantially. Individuals are increasingly willing to pay a high premium for clean air as they upgrade their consumption. The evolution of Chinese real estate

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development in the past decades suggest that there is plenty of potential to improve air quality at low cost, for example through modern garden design. Soaring housing prices offer a great profit opportunity for property developers to reap the premium by providing a better living environment. One can therefore expect that, the faster housing prices grow, the greater the incentive for private provision of public goods, and the better the air quality.

We study whether the housing market boom motivates public and private provision of public goods using province-level data in China. The first step is to investigate whether rising housing prices lead to better air quality. There is an emerging strand of literature that studies how air quality affects housing prices (Chay and Greenstone, 2005). It is therefore essential to control for the reverse causality running from air quality to housing prices. Instead of focusing on the unilateral impact, this paper explores the dynamic interaction between housing price growth and air quality using panel vector auto regression (VAR). VAR is a theory-free method that serves as an alternative style of identification and can practically perform useful forecasts and analysis on the magnitude and duration of bilateral interactions (Sims, 1980). It has been one of the most important tools in macroeconomic literature and is increasingly used in research areas such as finance, politics and technology (see for example Hasbrouck, 1991; Enders and Sandler, 1993; Erceg et al., 2005). We follow Holtz-Eakin (1988), Canova and Ciccarelli (2009) and Jinjarak et al. (2011) to estimate VAR in panel data. Our panel VAR consists of housing price growth and air quality, the two endogenous variables that interact with each other. This allows us to test whether lagged housing price growth has predictive power on current air quality, while accounting for the reverse causality. Such a panel VAR also allows us to analyze when, by how much, and how long a one-time shock to housing price growth will exert an impact on air quality while keeping all other factors constant.

The panel VAR estimation result provides evidence that higher housing price growth predicts better air quality, which fosters housing price growth. The results remain robust after we control for provincial fixed effects, time-varying macroeconomic conditions, economic structure and urbanization processes that could simultaneously affect housing price growth and air quality. In response to one standard deviation

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positive shock to housing price growth (8%), the air quality improves by 8% cumulatively over three years, which amounts to adding 23 good-air-quality days per year. The impact of housing price growth on improving air quality is more pronounced for provinces in the eastern part of China, first-tier and big cities (Beijing, Shanghai and Guangdong), and provinces that experience faster housing price growth than the median. In addition, the impact of housing price growth on air quality can be more clearly seen following the Global Financial Crisis (GFC), when major property developers started to incorporate green and energy-efficient neighbourhood design in residential projects.

After documenting robust evidence that higher housing price growth leads to better air quality, we proceed to uncover the channels of such a lead-lag effect. The housing market boom is accompanied by active transactions, which generates sizable fiscal revenues through, i.e. property transaction tax and stamp duties. According to China Tax Annual (2016), the real estate sector contributed to 28% of the local government's total tax revenue in 2015, which is more than triple that in 2001. This number is approximately doubled when accounting for tax related to housing constructions, and becomes even larger when further incorporating revenues related to land transactions. Given more fiscal revenues, local governments may be able to afford to allocate more resources to the environment on top of their pursuit of high GDP growth. To test for the public provision of clean air, we include government spending on environment protection in the panel VAR. We find significant evidence that housing price growth improves air quality by encouraging governments to invest more in environmental protection.

To test for the private provision of public goods, we consider the floor space of newly constructed buildings. If developers invest in landscaped green space and energy-efficient designs in new buildings, as more and more buildings are constructed and put into use, air quality will improve, at least in the long term. We argue that the profit opportunities in the real estate sector could motivate property developers to provide public goods that benefit air quality as home buyers become increasingly willing to pay a premium for clean air. In the early stages of economic development when wealth is low and consumption focuses on meeting basic needs, profit-

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maximizing property developers typically minimize investment in green areas. As the market undergoes a series of consumption upgrades, the demand for high-quality goods increases, housing functions not only as a shelter but also reflects the lifestyle of its owners. Housing prices in sought-after neighbourhoods were also more resilient to shocks during the GFC, which are attractive investment targets. The popularity of high-quality housing enables property developers to earn a significant premium by designing environment-friendly neighbourhoods that ultimate improve air quality. Our empirical findings reveal that higher growth in the floor space of new buildings improves air quality, which suggests that new buildings incorporate environmentally friendly elements. The result provides evidence that housing price growth contributes to air quality improvement by motivating more private investment in environment.

Other than testing for the public and private provision of clean air to decipher the relation between housing price growth and air quality, we also explore the role of structural change in land usage. The housing boom motivates the conversion of agricultural and industrial land to residential use. While concreting over farmland to build residential properties does undermine the ecological system, converting industrial land to residential drives polluting industrial firms out of the city and results in better air quality. However, we find no evidence that the positive impact of housing price growth on air quality is channelled through land conversion.

Our paper extends the study of environmental public goods by incorporating several different strands of literature. Since the classic works of Mills (1967) and Muth (1969), modeling of housing production and urban housing market remains to be the focus of urban and housing economics (Fisch, 1977; Brueckner, 1980, 1981; Quigley, 1984; Epple et al., 2010). The link of environmental goods provision to housing production receives surprisingly little attension. In this paper, we discuss the private provision of environemntal public goods in real estate firms' decision making. Following the analytical framework of Acemoglu (2002) where directed technical change is induced by factor biased innovation, we argue that increasing housing prices induces both producers and consumers to change their preferences, resulting in dynamic investment and purchasing strategies. The improvement of air quality is attributed to the increasing substitution towards environmentally friendly housing. Therefore, this

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study contributes to the literature on public economics by providing evidence on the private provision of environmental public goods in the housing market.

A second group of related literature lies in development economics, with a focus on public investment. The discussion of public investment in the literature is limited to either the driving forces (Hansen, 1965; Gang and Khan, 1990; Keefer and Knack, 2007) or its impact on development (Aschauer, 1989; Munnell, 1992; Cavallo and Daude, 2011). We discuss that public investment in environmental protection acts a channel to convert high housing price into better environmental quality. Higher housing price expands fiscal revenues and therefore encourages local governements to invest more in environment protection. By employing the panel VAR model, we find cross-sectional and time-varying heterogeneity. The dynamic interaction between air quality and housing prices is significant in the developed regions and also the eastern part of China, which confirms the result of Cho et al. (2008) that the values of amenity services vary with the level of economic development and the degree of urbanization. In addition, different from Pereira and Andraz (2005) who find that public investment crowds in private investment and employment in the transportation infrastructure in Portugal, we show that both public and private investment co-exist in the provision of environmental public goods.

Finally, this paper also bridges environmental management literature with real estate studies. While some studies focus on the constructions of various housing price indices (Englund et al., 1998; Gourieroux and Laferrere, 2009; Paredes, 2011), others seek to identify the dynamics between housing price and other macroeconomic factors. Ortalo-Magne and Rady (1999) show, in a life-cycle model with income heterogeneity and credit constraints, the co-movement of housing prices and owner occupancy rates is a response to income and credit market shocks. Chay and Greenstone (2005) find that air quality does influence housing prices by exploring the impact of the Clean Air Act. Our analysis demonstrates the environmental benefits of high housing price.

The rest of the paper is organized as follows. Section 2 describes the data and summary statistics. Section 3 presents the estimation methodology and empirical results. Section 4 explores the cross-sectional and time-varying heterogeneity, and uncovers the channels of such heterogeneity. Section 5 concludes.

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2 Data and Summary Statistics

We obtain from the China Statistical Yearbooks (CYS) the provincial panel data on housing prices, various macroeconomic indicators and environmental characteristics. All monetary variables (housing prices, GDP, GDP per capita) are adjusted to real terms in 2000 constant prices using provincial CPI. The provincial data is then merged with the air quality index, which is calculated as the number of days in a year that meet air quality health level grade II and is available for each provincial capital city since 2003.[1] All variables are then transformed into a logarithim. Air quality in a city is not only affected by economic activities within that city but also those nearby, which motivates us to focus on the relation between provincial production and city air quality. As a robustness check, we also employ alternative measures of air quality at provincial level. Appendix Tables 1 and 2 provide a description of these variables and their summary statistics based on the sample period of 2003-2015.

To prepare the data for panel VAR, we first test for the panel unit root in each of the two dependent variables as well as key control variables. Table 1 shows the CIPS statistics based on Pesaran (2007), which account for the heterogeneity across panels as well as the cross-panel dependence. The CIPS statistics cannot reject the null hypothesis of the unit root in the time series of housing prices (HP), regardless of whether province fixed effects or time trends are included. Housing price growth, measured by the first differences of log housing prices and denoted as DHP, becomes stationary. The CIPS statistics suggest that air quality (AQ) is stationary. We therefore include DHP, the log return of housing prices, and AQ, the log of air quality, as the dependent variables in the panel VAR.

The key control variables in this analysis are GDP per capita (PC), manufacturing output as a ratio of GDP (MO), and gross fixed asset formation (INV), which are found to affect both housing prices and air quality. GDP per capita is strongly correlated with housing prices (Englund and Ioannidesl, 1997) and its impact on air quality has been extensively discussed in the literature on the Environmental Kuznets

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[1] Air quality index intially covers only provincial capital cities and expands to a large set of cities since 2014.

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Table 1: Panel Unit Root Test.

Name (Variable)	Level: Fixed Effects	Level: Fixed Effects & Time Trends	First Difference: Fixed Effects	First Difference: Fixed Effects & Time Trends
Housing Prices (HP)	-2.18	-2.57	-3.52	-3.51
Air Quality (AQ)	-2.61	-3.28	-3.79	-3.64
GDP Per Capita (PC)	-1.39	-1.84	-2.28	-2.57
Manufacturing Output (MO)	-1.81	-2.05	-2.87	-2.68
Investment (INV)	-2.10	-2.02	-2.31	-2.45

Notes: The table reports the CIPS statistics developed by Pesaran (2007), which tests for the panel unit root of heterogeneous panels in the presence of cross-section dependence. The critical values to reject the null hypothesis of homogeneous non-stationarity at 1%, 5% and 10% significance levels are -2.38, -2.20 and -2.11, respectively, when considering province fixed effects (and time trend) in cross-sectionally augmented Im, Pesaran and Shin (IPS) t-bar test.

curve. The share of manufacturing output in GDP (MO) captures the effects of the industrial structure. Higher MO tends to lower air quality as China's manufacturing sector is fossil energy intensive while the decline in manufacturing is always associated with a housing boom (Charles et al., 2016). The variable INV measures the acquisition values of fixed assets for both the business sector and households, which are expected to affect both *DHP* and *AQ*. Table 1 shows that the three key control variables are non-stationary in levels and stationary after taking the first difference. We therefore include in the regression the first-differences of these control variables, namely *DPC*, *DMO* and *DINV*, which measure the growth in GDP per capita, manufacturing output, and investment, respectively. In the robustness anaysis, we further control for various macroeconomic and demographic variables that might affect either housing price growth or air quality.

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3 Estimation

3.1 Panel VAR specification

Soaring housing prices, which add substantial fiscal revenues and provide good profit opportunities, may motivate public and private investments in public goods such as clean air, which subsequently improve air quality. To test whether housing price growth contributes to clean air, it is important to control for the impact of air quality on housing prices (Chay and Greenstone, 2005). We explore the dynamic interaction between housing price growth and air quality based on a panel VAR with order p:

$$\begin{bmatrix} DHP_{i,t} \\ AQ_{i,t} \end{bmatrix} = \sum_{j=1}^{j=p} A_j \begin{bmatrix} DHP_{i,t-j} \\ AQ_{i,t-j} \end{bmatrix} + B \cdot X_{i,t} + C_i + \varepsilon_{i,t}, \tag{1}$$

where $\begin{bmatrix} DHP_{i,t} \\ AQ_{i,t} \end{bmatrix}$ is the vector of dependent (endogenous) variables that include the housing price growth DHP and air quality index AQ in each province, A_j is the (2×2) matrix that captures the coefficients for the j-period lagged endogenous variables, $X_{i,t}$ is the vector of exogenous control variables, B is the matrix of the coefficients of $X_{i,t}$, C_i is the (2×1) vector of province-fixed effects, and $\varepsilon_{i,t}$ is the (2×1) vector of serially uncorrelated error terms. In the main regression, the vector $X_{i,t}$ includes *DPC*, *DMO* and *DINV*, the growth in GDP per capita, manufacturing output, and investment, respectively.

To determine the optimal lag order p for the panel VAR, we set the maximum lag to be 5 and calculate the overall coefficient of determination (CD) for each lag order using GMM. Table 2 presents the statistics CD for the panel VAR with and without control variables $X_{i,t}$. The two sets of results are almost identical. Both specifications include the provincial fixed effects C_i. The statistics CD increases when the lag order goes from 1 to 2 and falls when the lag order rises further to 3. Although CD increases substantially when the lag is increased to 5, it reduces the sample size and is costly in terms of degree of freedom. To strike a balance between the model efficiency and parsimony of the model, we select $p = 2$ as the optimal lag. In the following, we will estimate the panel VAR with a lag order of 2.

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Table 2: Lag selection.

Lag	1	2	3	4	5
Without Control	0.18	0.22	0.21	0.26	0.51
With Control	0.18	0.22	0.21	0.26	0.61

Notes: The table reports the coefficient of determination (CD), the proportion of variation explained by the panel VAR model. It is calculated as $CD = 1 - det(\varepsilon'_{i,t}\varepsilon_{i,t})/det(\varOmega)$, where $det(\cdot)$ represents the determinants of the squared matrix in parentheses, $\varepsilon'_{i,t}\varepsilon_{i,t}$ is the variance matrix of the error terms, and $\varOmega$ is the unconstrained covariance matrix of the dependent variables.

3.2 Baseline results

Table 3 reports the estimation results from the panel VAR in Eq.(1) using the generalized method of moments (GMM). Columns (1) and (2) report the results without controlling for $X_{i,t}$, while columns (3) and (4) present results controlling for time variations in *DPC*, *DMO* and *DINV*, the annual growth in GDP per capita, manufacturing output share, and investment, respectively. Both model specifications include provincial fixed effects.

In columns (1) and (3), where the dependent variable is housing price growth (*DHP*), the coefficients of lagged air quality (*AQ*) are positive and statistically significant. Testing the null hypothesis that air quality does not Granger cause *DHP* yields a χ^2 of 24.86, which rejects the null hypothesis at the 1% significance level. In columns (2) and (4), where the dependent variable is *AQ*, the coefficients of the lagged *DHP* are also positive and statistically significant. The Granger causality test rejects the null hypothesis that *DHP* does not Granger cause *AQ* at the 1% significance level. The results provide evidence of dynamic feedback between housing price growth and air quality. In particular, an acceleration in housing price growth improves air quality while better air quality also promotes housing price growth.

Looking at columns (3) and (4), we find that the coefficients of control variables

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Table 3: Basic Panel VAR Estimation Results Based on GMM.

	Without Control		With Control	
	(1) *DHP*	(2) *AQ*	(3) *DHP*	(4) *AQ*
L.DHP	0.00	0.42***	0.05	0.28***
	(0.06)	(4.20)	(0.72)	(2.69)
L2.DHP	0.03	0.30***	0.05	0.28***
	(0.39)	(2.68)	(0.66)	(2.69)
L1.AQ	0.20***	0.86***	0.15***	0.59***
	(4.98)	(9.31)	(2.93)	(4.91)
L2.AQ	0.03*	-0.05	0.02	-0.16***
	(1.74)	(-0.93)	(0.60)	(-2.74)
DPC			0.11	1.10***
			(0.80)	(4.75)
DMO			-0.33	-0.34*
			(-1.63)	(-1.94)
DINV			0.20**	0.30**
			(2.17)	(2.47)
Observations	300	300	300	300
Granger causality test				
$AQ \rightarrow DHP$	$\chi^2 = 24.86, p-value < 0.01$		$\chi^2 = 12.38, p-value < 0.01$	
$DHP \rightarrow AQ$	$\chi^2 = 19.61, p-value < 0.01$		$\chi^2 = 10.91, p-value < 0.01$	

Notes: The dependent variables are *DHP*, the housing price growth, and *AQ*, the air quality. *L.* is the lag operator. *DPC*, *DMO* and *DINV* are the growth in GDP per capita, manufacturing output, and investment, respectively. T-statistics in parentheses, symbols *, **, and *** correspond to the significance level at 10%, 5%, and 1% respectively. All regressions control for region fixed effects.

are generally consistent with the existing literature. The growth in GDP per capita (*DPC*) is positively and significantly associated with air quality (*AQ*), suggesting

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that fast-growing regions enjoy better air quality. Higher growth in the manufacturing output as a ratio of GDP (*DMO*) is correlated with lower air quality, which is intuitive as manufacturing tends to be more polluting than other industries. *DHP* is positively associated with *DPC* but negatively associated with *DMO*, such relationships are however not significant. The growth in investment (*DINV*) is positively and significantly associated with both *DHP* and *AQ*, which suggests that increasing provincial investment contributes to the acceleration of housing price growth and improvement in air quality.

To have a better understanding of the dynamic interaction between *DHP* and *AQ*, we proceed to calculate the impulse response function (IRF) based on the panel VAR with control variables. Figure 1 shows the IRFs to a 1% shock in *DHP* and *AQ* respectively over 10 years. The top two panels plot the IRF of *AQ* and *DHP* to a 1% shock in *AQ*. In response to a 1% shock in *AQ*, the IRF of *AQ* quickly decays and becomes insignificant in 3 years, while the IRF of *DHP* goes up in the first year with a small magnitude and decays gradually to zero within a few years after the shock. As shown in the bottom panels, in response to a 1% shock in *DHP*, the IRF of *AQ* is positive and statistically significant at 0.28%, 0.46%, and 0.26%, respectively, in the first three years after the shock. This number diminishes gradually afterwards. Cumulatively, *AQ* increases by 1% after three years and 1.3% after 10 years. The IRF of *DHP* drops quickly and becomes insignificant in just a year. Recall from Appendix Table 2 that, on average, the number of days that meet air quality Grade II and above over one year are 284 in our sample, and that the standard deviation of housing price growth is 8%. For one standard deviation shock in housing price growth, the number of days featuring healthy air quality increases by 8% (=8%/1%*1%) or 23 days (=284*8%) three years after the shock. Comparing the IRF of *DHP* to an *AQ* shock (top right panel) and the IRF of *AQ* to a *DHP* shock (bottom left panel), we observe that air quality is sensitive to housing price growth but less so the other way around, in terms of both the magnitude of IRF and the duration of response.

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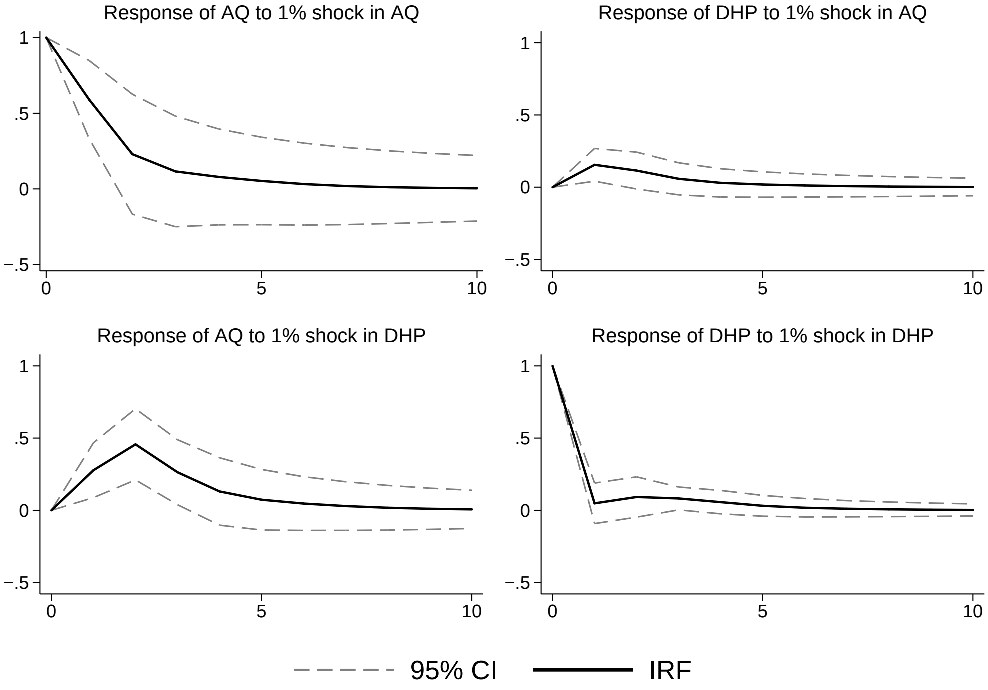

Figure 1: Impulse response function (IRF).

Note: Solid lines show the response of AQ (left panels) and DHP (right panels) to a 1% shock in AQ (top panels) and DHP (bottom panels) respectively. DHP and AQ refer to housing price growth and air quality respectively. The dashed lines represent the 95% confidence interval (CI). The x-axis is the number of years after the shock and the y-axis is the IRF in percentage.

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3.3 Robustness checks

3.3.1 Lag order

To check whether the results presented above are sensitive to the lag selection, we run the panel VAR with the same set of control variables, but vary the lag order from 1 to 5, and conduct the Granger causality tests accordingly. Table 4 shows the χ^2 and the corresponding p-values for the null hypothesis of no Granger causality. Regardless of the lag order, our finding that *DHP* and *AQ* Granger cause each other remains robust.

Table 4: Granger causality tests based on different lag order.

	H0: *AQ* does not cause *DHP*		H0: *DHP* does not cause *AQ*	
Lag	χ^2	p-value	χ^2	p-value
1	6.10	0.01	4.16	0.04
2	10.91	0.00	12.38	0.00
3	7.26	0.06	11.97	0.01
4	17.74	0.00	29.24	0.00
5	19.12	0.00	52.82	0.00

Notes: *DHP* and *AQ* refer to housing price growth and air quality respectively. This table reports χ^2 and the corresponding p-value from the Granger causality tests based on the panel VAR with the lag order ranging from 1 to 5. Exogenous variables as in Table 3 are included.

3.3.2 Alternative measures of air quality

A natural concern is whether the Granger causal relationships between housing price growth and air quality continue to hold if an alternative measure of air quality is employed. So far we have been using *AQ*, the logarithimic number of days that meet air quality Grade II and above over one year, which is stationary in levels. We include the level instead of the first difference of AQ as a dependent variable in the panel VAR so as to retain as much information about the air quality as possible. However,

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given that the other independent variable is the first difference of housing price and all control variables are also in their first difference, it may appear straightforward to explain the dynamic relation between air quality and housing price if both are in their first difference. We therefore replace AQ in Eq.(1) with DAQ, the growth rate in the number of good-air-quality days in a year, and repeat the analysis. The panel estimation results in Appendix Table 3 show that the coefficients of lagged DHP in the regression of DAQ are positive and statistically signfiicant, which is consistent with the main finding that higher housing price growth is associated with better air quality. The Granger causality tests summarized in Table 5 also produce results indicating that housing price growth Granger causes air quality improvement. There is however no evidence that air quality improvement Granger causes housing price growth.

One may be concerned that the air quality index for the capital cities is not representative of the overall air quality in a province. To address this concern, we explore alternative measures of air quality at province level. The first measure is *DSO2*, the annual growth rate in the volume of sulphur dioxide emissions per year.[2] The higher the value of *DSO2*, the faster the air quality deteriorates. The panel VAR and Granger causality test results are reported in Appendix Table 3 and Table 5 respectively. Consistent with the previous findings, we find that higher housing price growth in the past two months is associated with lower current *DSO2*. There is significant evidence that housing price growth Granger causes air quality measured in *DSO2*. We also measure air quality with *DPW_PM2.5* and *DGM_PM2.5*, which refer to the growth in population-weighted and geographic-mean PM2.5 respectively. Appendix Table 3 shows that higher housing price growth is associated with air quality improvement, as indicated by the negative coefficients of lagged *DPW_PM2.5* and *DGM_PM2.5*. However, the results are not statistically significant.

As we show later, the Granger causality is mainly driven by the post-crisis periods when environmental friendly designs are more prevalent. We therefore re-evaluate the Granger causal relationship between housing price growth and air quality using a post-

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[2] We focus on DSO2 because he average concentration of SO2 per year is non-stationary.

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crisis subsample. The Granger causality tests in Table 5 reveal significant evidence that higher housing price growth Granger cause air quality improvement, regardless of the measures of air quality.

Table 5: Granger causality tests based on alternative measures of air quality.

	H0: Air quality does not cause *DHP*		H0: *DHP* does not cause air quality	
Panel A: Full sample				
Measures of air quality	χ^2	p-value	χ^2	p-value
DAQ	3.98	0.14	5.12	0.08
DSO2	32.75	0.00	18.54	0.00
DPW_PM2.5	2.69	0.26	6.80	0.03
DGM_PM2.5	2.12	0.35	6.12	0.05
Panel B: Post-Crisis subsample				
Measures of air quality	χ^2	p-value	χ^2	p-value
DAQ	18.08	0.00	8.37	0.02
DSO2	25.04	0.00	18.69	0.00
DPW_PM2.5	2.92	0.23	12.52	0.00
DGM_PM2.5	2.30	0.32	12.13	0.00

Notes: This table reports χ^2 and the corresponding p-value from the Granger causality tests based on the panel VAR of *DHP* and alternative measures of air quality (*DAQ*, *SO2*, *DSO2*), *DPW_PM2.5* and *DGM_PM2.5* with the lag order of 2. *DHP* refers to housing price growth. *DAQ* is the growth in air quality, *SO2* is the logarithmic annual average concentration of *SO2* and *DSO2* is the growth rate of *SO2*. *DPW_PM2.5* and *DGM_PM2.5* are the growth in population-weighted and geographic-mean PM2.5 respectively. Exogenous variables as in Table 3 are included.

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3.3.3 Additional control variables

To mitigate the concern that these results can be driven by omitted variables that move *DHP* and *AQ* in the same direction, we control for additional macroeconomic variables. We also include in the regressions the growth in the service sector output as a ratio of GDP (*Dservice*), the growth in the urbanization process calculated as the ratio of urban population to total population (*Durban*), and the growth in population density (*Ddensity*). The results are presented in columns (1) and (2) in Appendix Table 4. The estimated coefficients on the lagged dependent variables and Granger causality tests are consistent with our main findings that air quality and housing price growth reinforce each other. We also find that a greater weight in the service sector is associated with higher housing price growth and better air quality. The urbanization process *Durban* accelerates housing price growth at a 10% significance level. The coefficient of *Ddensity* is positive but insignificant in the regressions of both *DHP* and *AQ*.

4 Further Analysis

After documenting robust evidence that housing price growth enhances air quality, we proceed to check whether such a relation between housing price growth and air quality varies across provinces and over time. Since the evidence that *AQ* Granger causes *DHP* is already well addressed in literature, we focus on the impact of housing price growth on air quality across different regions in this section.

4.1 Cross-sectional heterogeneity

We first group the provinces into three official categories, eastern, western and central China, which correspond to distinct geographic locations with different growth models and natural environments. The estimated coefficients for the cross-sectional heterogeneity are reported in Appendix Table 5. Table 6 reports the Granger causality test statistics. The χ^2 statistics are 8.65, 6.11, and 7.15 for eastern, western, and central part of China respectively, which reject the null hypothesis that *AQ* does not

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Granger cause *DHP* at the 5% significance level. However, we only find evidence that *DHP* Granger causes *AQ* for the eastern part of China. Comparing the cumulative IRF (CIRF) for the 3 subsamples, we observe from the top left panel of Figure 2 that, cumulatively, air quality responds most vigorously to the shock in housing price growth in eastern China. In particular, a 1% shock in *DHP* could lead to a 2% increase in air quality over 6 years and this impact stabilizes thereafter. The result indicates that one standard deviation shock to *DHP* (8%) can add 45 (284*16%) good-air-quality days 6 years after the shock.

One may suspect that the strong results for eastern China are driven by the first-tier cities, which have a fast-growing housing market and a unique business model that may not be representative of China as a whole. To address this concern, we split the sample into 2 subsamples: first-tier markets (Beijing, Shanghai and Guangdong) and other markets. The Granger causality test in Panel B of Table 6 suggests that the previous results were not driven by the unique characteristics of first-tier markets. There is evidence of mutual reinforcement between *DHP* and *AQ* for both subsamples. However, it is true that, the CIRF of *AQ* in response to a 1% shock in *DHP* is much higher for first-tier markets than for the others (see the top right panel of Figure 2).

Housing prices may have to grow sufficiently fast to motivate developers to improve the environment. If this is the case, we will find the empirical relationship between housing price growth and air quality to be more apparent for provinces with a stronger housing market. To test the heterogeneity between high-growth and low-growth regions, we first calculate the average housing price growth for each province, and run panel VAR for two subsamples such that one includes provinces whose average housing price growth is higher than the median (High Growth subsample), while the other includes those below the median (Low Growth subsample). The Granger causality tests suggest that *AQ* Granger causes *DHP* in both subsamples, while *DHP* Granger causes *AQ* in the High Growth subsample only. We observe from the bottom left panel of Figure 2 that the air quality in high-growth housing markets is much more responsive to housing price growth than that in the low-growth housing markets. Our finding that higher housing price growth leads to better air quality is mainly driven by provinces that experience high growth in housing markets.

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Table 6: Cross-sectional heterogeneity in the relation between housing price growth and air quality.

	H0: AQ does not cause DHP		H0: DHP does not cause AQ	
	χ^2	p-value	χ^2	p-value
Panel A				
East	8.65	0.01	9.85	0.01
West	6.11	0.05	0.75	0.69
Middle	7.15	0.03	2.95	0.23
Panel B				
First Tier	7.57	0.02	21.60	0.00
Others	14.72	0.00	8.19	0.02
Panel C				
Low Growth	5.46	0.07	1.78	0.41
High Growth	14.08	0.00	9.38	0.01

Notes: This table reports χ^2 and the corresponding p-values from the Granger causality tests based on the panel VAR in Eq.(1). *DHP* and *AQ* are housing price growth and air quality, respectively. In Panel A, East, West and Middle refers to the geographic classification of Chinese provinces. In Panel B, the sample is decomposed into First-Tier regions that include Beijing, Shanghai and Guangdong and others. In Panel C, regions are classified in to low and high growth markets according to whether their average housing price growth are below or above national median value. Exogenous variables as in Table 3 are included.

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4.2 Before and after the Global Financial Crisis

The concept of neighborhood design did not become prevalent until after the 2007 Global Financial Crisis (GFC). China exhibited a delayed response to the GFC, with both stock and housing markets being hit most severely in 2009. During this period, China released a stimulus package worth RMB4 trillion (US$586 billion), which mostly flowed into the real estate market. Although most markets recovered fairly quickly from the crisis, well-designed residential projects seem to be especially resilient to these shocks. As a result, home buyers place a higher value on good design and are more willing to pay a premium for quality neighborhoods, which motivates real estate developers to invest more on landscape design. Meanwhile, rapid economic growth has increased household wealth substantially while worsening air pollution. As households become increasingly conscious of the importance of good health, they demand more clean air, which has become scarce, thus driving up the valuation of clean air. Against this background, we split the sample into two intervals, namely 2003-2008 when neighborhood design was relatively niche, and 2009-2015, when landscape design gained prominence.

The difficulty with running separate regression models for each interval is that we do not have sufficient observations to evaluate two subsamples individually. Therefore, we introduce interaction terms between the lagged dependent variables and a pre-crisis dummy that equates to one if the observation occurs in 2003-2008 and zero otherwise. The interaction terms are generally not significant, except for the interaction between the two-year lagged *DHP* and the pre-crisis dummy. The panel VAR estimation results, augmented by interaction terms, are presented in Table 7. This shows that higher housing price growth leads to better air quality only after the GFC. Evaluating the CIRF of *AQ* to a 1% shock in *DHP*, we observe from the bottom right panel in Figure 2 that air quality is much more responsive to the housing market shock during 2009-2015 than during 2003-2008. In particular, one standard deviation shock to the housing price growth (8%) after the GFC can add 54 (284*8%*2.4) good-air-quality days 10 years after the shock. The results support our argument that rising housing price growth is conductive to the improvement of air quality when green buildings

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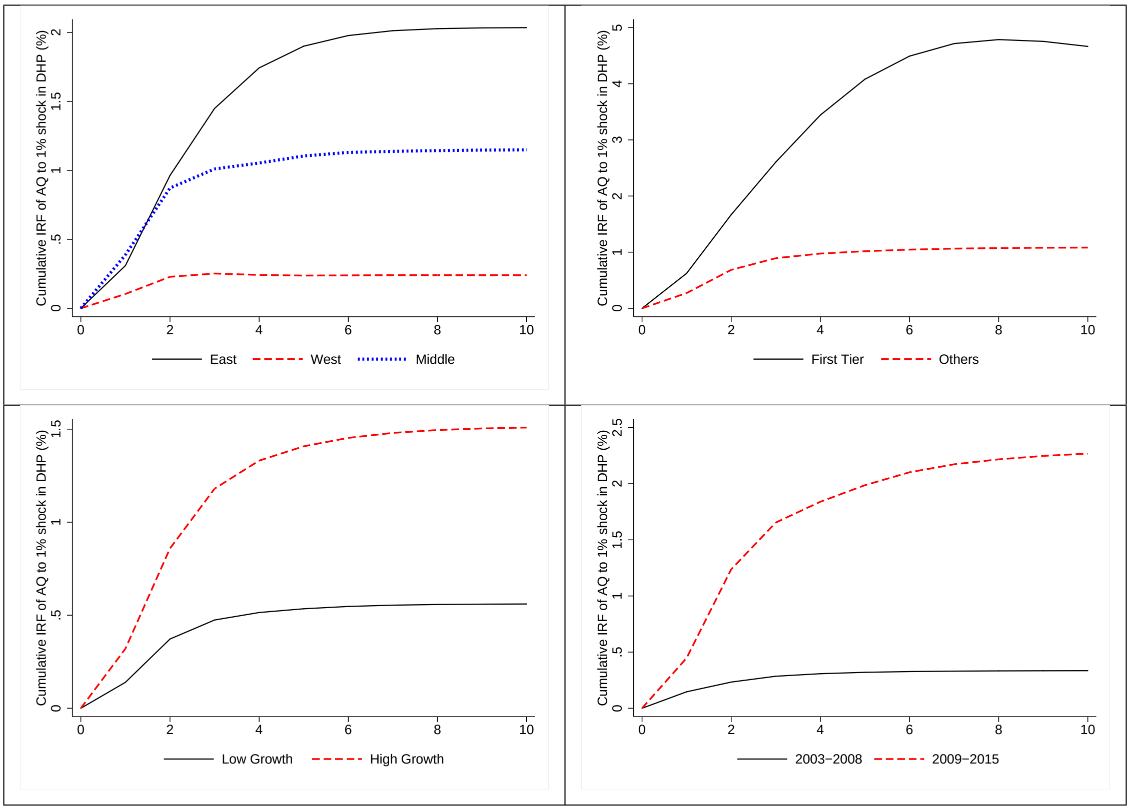

Figure 2: Cumulative IRF across different classifications.

and landscape design become prevalent.

4.3 Channels through which housing prices improve air quality

So far we have documented significant evidence that higher housing price growth leads to better air quality, which is more pronounced in more developed regions, faster-growing housing markets, and after the GFC. In this section, we further explore the channels through which housing price growth improves air quality.

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Table 7: Time-variation in the relation between air quality and housing price growth.

	DHP	*AQ*		*DHP*	*AQ*
L.DHP	0.07	0.45**	*L.DHP*PreCrisis*	-0.06	-0.30
	(0.69)	(2.48)		(-0.46)	(-1.45)
L2.DHP	-0.04	0.51***	*L2.DHP*PreCrisis*	0.22	-0.50***
	(-0.51)	(3.02)		(1.61)	(-2.73)
L1.AQ	0.17***	0.56***	*L1.AQ*PreCrisis*	-0.21	-0.03
	(3.56)	(4.81)		(-1.12)	(-0.15)
L2.AQ	0.01	-0.17***	*L2.AQ*PreCrisis*	0.21	0.04
	(0.49)	(-2.76)		(1.12)	(0.23)
Observations	300	300			

Notes: The dependent variables are *DHP*, the housing price growth, and *AQ*, the air quality. L*. is the lag operator. *PreCrisis* is a dummy variable that equals 1 for observations in the period 2003-2008. T-statistics in parentheses, symbols *, **, and *** correspond to the significance level at 10%, 5%, and 1% respectively. Exogenous variables as in Table 3 are included. All regressions control for region fixed effects.

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4.3.1 Public provision of public goods

The housing market boom in recent decades has generated substantial fiscal revenues for local governments. The surging housing prices increase the value of the land, which enables local land-owning governments to auction this resource at a higher price. Despite a decline in the size of land auctioned, in 2017 land sale revenues still contributed 36% of local governments' fiscal revenue according to the Ministry of Finance (MOF). The active transactions fueled by the housing market boom have also brought about significant tax revenues such as stamp duty and property-related tax, which account for 12% of local governments' fiscal revenues in 2017 according to MOF. Higher housing price growth increases the fiscal revenues, which relaxes local government budget constraints. Local governments often prioritize investment projects that directly enhance GDP growth such as infrastructure construction. However, with loose budget constraints, they are more likely to provide public goods that benefit the long-term sustanability of economic growth. We test whether higher housing price growth that expands fiscal revenues encourages local governments to invest more in environment protections. If higher housing price growth leads to better air quality by encouraging more public provision of public goods, we will expect higher housing price growth to result in more investment in environment protections, which will subsequently improve air quality. To test for such a hypothesis on public provision of public goods, we expand Eq.(1) to include an additional endogeneous variable, the growth in government expenditure on environment protection (*DEEP*) such that

$$\begin{bmatrix} DHP_{i,t} \\ DEEP_{i,t} \\ AQ_{i,t} \end{bmatrix} = \sum_{j=1}^{j=p} A_j \begin{bmatrix} DHP_{i,t-j} \\ DEEP_{i,t} \\ AQ_{i,t-j} \end{bmatrix} + B \cdot X_{i,t} + C_i + \varepsilon_{i,t}. \tag{2}$$

The Granger causality tests in Table 8 and the panel VAR estimation results in Appendix Table 6 provide evidence of public provision of public goods being driven by housing prices. In particular, higher housing price growth accelerates government expenditure on environment protections, which leads to better air quality.

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4.3.2 Private provision of public goods

High-quality neighborhoods are often more resilient to price shocks. They not only provide good investment value but also pleasant living environments that benefit health and happiness. With rising income as well as growing financial and environmental literacy, middle- and upper-income earners in China become more and more willing to pay a premium for high-quality properties. Indeed Petit et al. (1995) and Cho et al. (2008) document that environmental amenities such as green spaces and gardens enhance the market value of properties. In reality, apartments with lake or park views are normally sold at higher prices compared to those without, yet they are sought after by keenly by property-buyers. To meet the rising demand of high-quality property and enhance profit margins, real estate developers are motivated to design and construct environmentally friendly neighborhoods. Unlike previous eras when trees were removed, rivers were reclaimed and traditional buildings were torn down to facilitate construction and maximize land usage, today real estate developers not only preserve natural settings like parks and rivers, but also landscape man-made parks, lakes and cultural scenes around residential buildings to create an enjoyable living environment. Such private provision of public goods generates significant externalities that may ultimately improve air quality.

The evolution of housing development and air quality in the past decade in China provides a great opportunity to study the private provision of clean air through housing market development. If clean air is universally available throughout the sample period, home buyers can enjoy fresh air at no cost and would have no incentive to pay a premium for it. If the premiums home buyers are willing to pay are not sufficiently high, real estate developers may not generate sufficient income to cover their additional investment in environmentally friendly design and construction. If real estate construction in China had already been fully developed, it would be either too costly or too difficult to make alterations to improve the enviroment further. In both scenarios, profit-seeking real estate developers would have little incentive to invest in environmental conservation or enhancement. In China, clean air becomes more and more scarce, especially in big cities, while the demand for it escalates as individuals

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become more aware of the harm of air pollution. Both of these factors increase the market value of clean air and provide good profit opportunities for real estate developers. Moreover, there is relatively limited garden, landsape, and green space in private properties built before the GFC. It was not until after the GFC that neighborhood design catering to high-end projects gained prominence. In such a context, by investing in environmental amentities, real estate developers can make visible differences and reap the premiums for high-quality properties.

We expect higher housing price growth to provide better profit opportunities for real estate developers and motivate them to invest more in environmentally related design and construction, which subsequently improves air quality. If real estate developers invest in environmentally friendly elements, we should expect more new residential constructions to be associated with more environmentally related investment and therefore better air quality. To explore whether housing price growth improves air quality through the channel of encouraging private provision of public goods, we expand Eq.(1) to include an additional endogeneous variable - the growth in the floor space of new buildings (*DFS*) such that

$$\begin{bmatrix} DHP_{i,t} \\ DFS_{i,t} \\ AQ_{i,t} \end{bmatrix} = \sum_{j=1}^{j=2} A_j \begin{bmatrix} DHP_{i,t-j} \\ DFS_{i,t} \\ AQ_{i,t-j} \end{bmatrix} + B \cdot X_{i,t} + C_i + \varepsilon_{i,t}. \tag{3}$$

The Granger causality tests in Table 8 and the panel VAR estimation results in Appendix Table 6 provide evidence on the private provision of public goods. In particular, we find that higher housing price growth leads to faster growth in newly built floor space, which contributes to better air quality. It is true that the construction of new buildings may be associated with air pollution during the period of construction. Note that the Granger causality captures the relation between new floor spaces built in previous years and the current air quality. By the time the constructions are completed and put into use, the environmentally friendly new buildings with green space and gardens would start to improve air quality.

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Table 8: Channels through which housing price growth improve air quality.

Panel A: Public provision of public goods

H0: *DHP* does not cause *DEEP*		H0: *DEEP* does not cause *AQ*	
χ^2	p-value	χ^2	p-value
8.29	0.02	8.88	0.06

Panel B: Private provision of public goods

H0: *DHP* does not cause *DFS*		H0: *DFS* does not cause *AQ*	
χ^2	p-value	χ^2	p-value
7.82	0.02	32.92	0.00

Notes: Panels A and B of this table report χ^2 and the corresponding p-values from the Granger causality tests based on the panel VAR specified in Eq.(2) and (3) respectively. *DEEP* is the growth in public expenditure on environmental protection and *DFS* is the growth in the floor space of new buildings. *DHP* and *AQ* are housing price growth and air quality respectively. Exogenous variables as in Table 3 are included.

4.3.3 Other Channels

Other than testing for the public and private provision of clean air to decipher the relation between housing price growth and air quality, we also explore the role of structural changes in land usage. The housing boom may motivate the conversion of industrial land to residential use, which could potentially drive polluting industrial firms out of the city and result in better air quality. However, we find no evidence that the positive impact of housing price growth on air quality is channelled through land conversion, as revealed by the panel VAR estimation results in Appendix Table 7. The results may be driven by the aggregation of data on industrial land, which also covers land allocated to new industrial parks that are not polluted.

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5 Conclusion

We explore the dynamic interaction between housing price growth and air quality in Chinese provinces using panel VAR. We find consistent evidence that higher housing price growth leads to better air quality, even after accounting for the reverse causality running from air quality to housing price growth. Such a relationship is particularly pronounced for provinces with rapid housing price growth and after the GFC. In particular, one standard deviation positive shock to housing price growth (8%) can increase the number of good-air-quality days by 54 after the GFC in the long run. We also provide empirical evidence that housing price growth improves air quality by motivating both public and private provision of clean air. Soaring housing prices add substantial fiscal revenues that enable local government to invest more in environmental conservation and protection, which leads to better air quality. The increasing demand for environmentally friendly living space motivates profit-seeking real estate developers to invest more in green spaces and gardens that in turn improve air quality. These findings suggest that housing market dynamics could be an effective mechanism to enhance both public and private provisoin of public goods.

An important caveat in relation to our study is the lack of analysis of the more direct channels through which housing price growth may affect air quality, such as green space, energy-efficient design, and industrial production upgrades. We leave the roles of these environmental activities for future studies when the data becomes available.

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Appendix: Tables

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Appendix Table 1: Variable definitions.

Variable	Description
HP	The logarithm of rverage selling price in RMB per square meter, constant 2000 prices price
AQ	The logarithm of the number of days within one year meets Grade II and Above standard
PC	The logarithm of real per capita GDP, constant 2000 prices
MO	The logarithm of manufacturing output as a ratio of total GDP
INV	The logarithm of Gross fixed capital formation in 100 million RMB
SO2	The logarithm of the annual average concentration of *SO2*
INDland	The logarithm of land for industrial use in square kilometer
DHP	The annual growth rate in housing prices
DPC	The annual growth rate in GDP per capita
DMO	The annual growth rate in the manufacturing output deflated by GDP
DINV	The annual growth rate in investment
Dservice	The annual growth rate in the service sector output as a ratio of GDP
Durban	The annual growth rate in the ratio of urban population to total population
Ddensity	The annual growth rate in population density
DSO2	The annual growth rate in the average concentration of *SO2*
DPW_PM2.5	The annual growth rate in population-weighted PM2.5
DGM_PM2.5	The annual growth rate in geographic-mean PM2.5
DEEP	The annual growth in government expenditure on environment protection
DFS	The annual growth rate in the floor space of new buildings

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Appendix Table 2: Summary Statistics.

Variable	Variable	Obs	Mean	Std. Dev.	Min	Max
Housing Prices	HP	360	8.07	0.52	7.15	9.75
Air Quality	AQ	360	5.65	0.25	3.89	5.90
GDP Per Capita	PC	360	10.09	0.67	8.26	11.51
Manufacturing Output	MO	360	-0.76	0.20	-1.62	-0.49
Investment	INV	360	8.65	1.04	5.67	10.79
Housing price growths	DHP	360	0.07	0.08	-0.19	0.45
GDP per Capita Growth	DPC	360	0.14	0.06	0.00	0.29
Growth of Manufacturing Output	DMO	360	-0.01	0.05	-0.24	0.11
Growth of investment	DINV	360	0.20	0.09	-0.32	0.47

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Appendix Table 3: Alternative Measures of Air Quality.

	Alt = *DAQ*		*Alt* = *DSO2*		*Alt* = *DPW_PM25*		*Alt* = *DGM_PM25*	
Panel A: Full Sample								
	DHP	*DAQ*	*DHP*	*SO2*	*DHP*	*DSO2*	*DHP*	*DGM_PM25*
L.DHP	0.01	0.39**	0.24***	-0.34	0.24***	0.24**	0.24***	0.23**
	(0.08)	(2.26)	(3.25)	(-0.97)	(3.30)	(2.53)	(3.26)	(2.39)
L2.DHP	0.08	0.33*	0.22***	-1.53***	0.26***	0.00	0.26***	0.00
	(0.64)	(1.76)	(2.66)	(-4.28)	(3.09)	(0.02)	(3.10)	(0.01)
L.Alt	0.10*	-0.11	0.07***	-0.34***	0.01	-0.22***	0.02	-0.20***
	(1.86)	(-1.35)	(5.22)	(-4.18)	(0.12)	(-3.22)	(0.44)	(-2.85)
L2.Alt	0.11	-0.16	-0.01	-0.20***	0.08	-0.11*	0.07	-0.09
	(1.58)	(-1.46)	(-1.02)	(-3.30)	(1.56)	(-1.92)	(1.45)	(-1.61)
Observations	270	270	270	270	300	300	300	300
Panel B: Post-GFC subsample								
	DHP	*DAQ*	*DHP*	*SO2*	*DHP*	*DSO2*	*DHP*	*DGM_PM25*
L.DHP	-0.02	0.68***	0.40***	-1.27***	0.36***	-0.23**	0.35***	-0.26**
	(-0.17)	(2.78)	(3.72)	(-2.98)	(3.66)	(-2.28)	(3.65)	(-2.50)
L2.DHP	-0.08	0.65**	0.22*	-1.52***	0.26**	-0.36***	0.26**	-0.36***
	(-0.65)	(2.52)	(1.94)	(-4.06)	(2.23)	(-3.27)	(2.25)	(-3.11)
L.Alt	0.18***	-0.32***	0.07***	-0.02	-0.02	-0.42***	-0.01	-0.40***
	(4.15)	(-2.91)	(3.84)	(-0.30)	(-0.32)	(-4.34)	(-0.17)	(-3.83)
L2.Alt	0.20***	-0.42***	-0.03*	-0.06	0.10	-0.27***	0.10	-0.23**
	(3.67)	(-2.95)	(-1.82)	(-1.14)	(1.26)	(-3.01)	(1.19)	(-2.51)
Observations	180	180	180	180	180	180	180	180

Notes: This table reports the estimation results based on the panel VAR of *DHP* and alternative measures of air quality, including (*DAQ*, *SO2*, *DSO2*), *DPW_PM2.5* and *DGM_PM2.5* with the lag order of 2. *DHP* refers to housing price growth. *DAQ* is the growth in air quality, *SO2* is the logarithmic annual average concentration of *SO2* and *DSO2* is the growth rate of *SO2*. *DPW_PM2.5* and *DGM_PM2.5* are the growth in population-weighted and geographic-mean PM2.5 respectively. Exogenous variables as in Table 3 are included. T-statistics in parentheses, symbols *, **, and *** correspond to the significance level at 10%, 5%, and 1% respectively. All regressions control for region fixed effects.

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Appendix Table 4: Controlling for additional variables.

	(1) *DHP*	(2) *AQ*
L.DHP	0.04	0.27**
	(0.66)	(2.42)
L2.DHP	0.05	0.28***
	(0.68)	(2.67)
L.AQ	0.14***	0.57***
	(2.92)	(4.67)
L2.AQ	0.01	-0.17***
	(0.25)	(-2.90)
DPC	0.14	1.17***
	(1.03)	(4.69)
DMO	-0.18	-0.16
	(-0.88)	(-0.86)
DINV	0.22**	0.30**
	(2.44)	(2.41)
Dservice	0.12**	0.21***
	(2.50)	(3.00)
Durban	0.13*	-0.08
	(1.67)	(-0.70)
Ddensity	0.63	0.52
	(0.85)	(0.52)
Observations	300	300
Granger causality test		
$AQ \rightarrow DHP$	$\chi^2 = 11.68$, $p - value < 0.01$	
$DHP \rightarrow AQ$	$\chi^2 = 10.62$, $p - value < 0.01$	

Notes: T-statistics in parentheses, symbols *, **, and *** correspond to the significance level at 10%, 5%, and 1% respectively. All regressions control for region fixed effects.

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Appendix Table 5: Cross-Sectional Heterogeneity.

	Eastern (1) *DHP*	Western (2) *DHP*	Central (3) *DHP*	First Tier (4) *DHP*	Others (5) *DHP*	Low Growth (6) *DHP*	High Growth (7) *DHP*
L.DHP	0.22**	-0.11	-0.13	0.03	0.09	-0.09	0.10
	(2.23)	(-1.14)	(-0.89)	(0.48)	(0.46)	(-1.00)	(1.22)
L2.DHP	0.11	-0.01	-0.08	0.04	-0.03	0.01	0.05
	(1.11)	(-0.04)	(-0.62)	(0.54)	(-0.21)	(0.05)	(0.54)
L1.AQ	0.08	0.18*	0.24***	0.16***	0.18	0.11	0.15**
	(1.05)	(1.85)	(2.67)	(3.83)	(0.79)	(1.59)	(2.12)
L2.AQ	-0.05	0.12*	0.02	0.03	-0.26**	0.07	-0.01
	(-1.10)	(1.82)	(0.60)	(1.56)	(-2.38)	(1.52)	(-0.31)
	AQ	*AQ*	*AQ*	*AQ*	*AQ*	*AQ*	*AQ*
L.DHP	0.31	0.10	0.39	0.62***	0.27**	0.14	0.32**
	(1.51)	(0.78)	(1.58)	(4.58)	(2.29)	(0.94)	(2.21)
L2.DHP	0.40***	0.09	0.34	0.51***	0.25**	0.17	0.32**
	(2.99)	(0.57)	(1.17)	(2.83)	(2.07)	(1.23)	(2.26)
L1.AQ	0.60***	0.42**	0.50**	0.77***	0.55***	0.55***	0.58***
	(3.51)	(2.14)	(2.02)	(3.49)	(4.22)	(3.58)	(3.64)
L2.AQ	-0.16**	-0.21	-0.18*	0.05	-0.18***	-0.11	-0.19**
	(-2.18)	(-1.46)	(-1.65)	(0.28)	(-2.91)	(-1.11)	(-2.57)
Observations	110	110	80	30	270	150	150

Notes: This table reports the panel VAR estimation based on different grouping of provinces. All regressions control for provincial fixed effects and time-varying provincial characteristics (not reported) as in Table 3. T-statistics in the parenthesis. Symbols *, **, and *** correspond to significance level at the 10%, 5%, and 1% respectively.

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Appendix Table 6: Channels through which housing price growth improves air quality.

	Public Provision			Private Provision		
	(1) *DHP*	(2) *DAQ*	(3) *DEEP*	(4) *DHP*	(5) *DAQ*	(6) *DFS*
L.DHP	0.07	0.43	0.54**	0.05	0.25**	0.16**
	(0.75)	(1.55)	(2.49)	(0.76)	(2.24)	(2.02)
L2.DHP	-0.05	0.22	-0.18	0.10	0.30***	0.04
	(-0.53)	(1.08)	(-0.93)	(1.36)	(2.85)	(0.50)
L1.AQ	-0.04	0.40***	-0.01	0.11**	0.56***	0.16***
	(-1.07)	(3.02)	(-0.07)	(2.25)	(4.79)	(4.35)
L2.AQ	-0.08***	-0.18***	-0.26***	0.00	-0.17***	0.05**
	(-2.73)	(-3.03)	(-4.20)	(0.08)	(-2.95)	(2.04)
L.DEEP	-0.01	0.04	-0.07			
	(-0.20)	(0.39)	(-0.60)			
L2.DEEP	-0.01	0.29***	0.04			
	(-0.27)	(2.72)	(0.50)			
L1.DFS				0.05***	0.02*	0.00
				(4.66)	(1.90)	(0.19)
L2.DFS				0.01	0.02	-0.05***
				(0.69)	(1.53)	(-4.31)
Observations	150	150	150	300	300	300

Notes: This table reports the estimation results based on the panel VAR specified in Eq.(2) and (3) respectively. *DEEP* is the growth in public expenditure on environmental protection and *DFS* is the growth in the floor space of new buildings. *DHP* and *AQ* are housing price growth and air quality respectively. Exogenous variables as in Table 3 and province fixed effects are included. T-statistics in the parenthesis. Symbols *, **, and *** correspond to significance level at the 10%, 5%, and 1% respectively.

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Appendix Table 7: The role of industrial land

	(1)	(2)	(3)
VARIABLES	DHP	AQ	INDland
L.DHP	0.19	-0.11	-0.14
	(0.76)	(-0.25)	(-0.89)
L2.DHP	0.09	0.23	-0.03
	(0.69)	(0.98)	(-0.40)
L.AQ	0.30	0.22	-0.04
	(1.31)	(0.55)	(-0.30)
L2.AQ	0.04	-0.23**	-0.00
	(0.67)	(-2.25)	(-0.12)
L.INDland	0.78	-1.42	0.47
	(0.90)	(-0.87)	(0.74)
L2.INDland	0.06	-0.50	0.09
	(0.29)	(-1.59)	(0.69)
Observations	300	300	300

Notes: This table reports the estimation results based on the panel VAR that explore the dynamic interaction among the housing price growth *DHP*, the air quality *AQ* and the size of land for industrial usage *INDland*. Exogenous variables as in Table 3 and province fixed effects are included. T-statistics in the parenthesis. Symbols *, **, and *** correspond to significance level at the 10%, 5%, and 1% respectively.

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