Determination of Urban Land and Housing Prices in China: A Simultaneous Equations Approach*

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Abstract

Using urban economic theories and econometric methods, this paper examines the determinants of land and housing prices and their relationship to the Chinese urban economy. The simultaneous equations approach is used to analyze a dataset of 35 major Chinese cities for the period 2003 to 2008 in which 2SLS and 3SLS are used to address the issue of endogeneity. The results of econometric estimation show that land prices and interest rates are important factors affecting housing prices. Furthermore, housing prices and two other factors relating to Chinese land institutions play significant roles in the determination of land prices: the extent to which the local government relies on fees for land use rights and the degree of marketization in the granting of land use rights. This empirical evidence indicates a bidirectional influence between land prices and housing prices in the Chinese urban economy. It also shows that the progress of marketization in the granting of land use rights raises land prices, thereby pushing up housing prices. The evidence also suggests that the reliance of the local government on fees for land use rights has contributed to the recent increase in land and housing prices, thus causing many social and economic problems in Chinese society.

Keywords: land prices, housing prices, simultaneous equations model, China's urban economy

1 Introduction

Since the beginning of this century, Chinese cities have experienced dramatic variations in both land and housing prices. Figure 1 depicts the price indices of urban land and housing in Beijing and Shanghai from 2002 to 2008. Price changes of this magnitude and speed naturally attract great attention from investors, public officials and scholars who saw the results of Japanese land price bubble in the 1980s and the collapse of U.S. housing markets in 2007. Figure 1 also shows that both land and housing prices have

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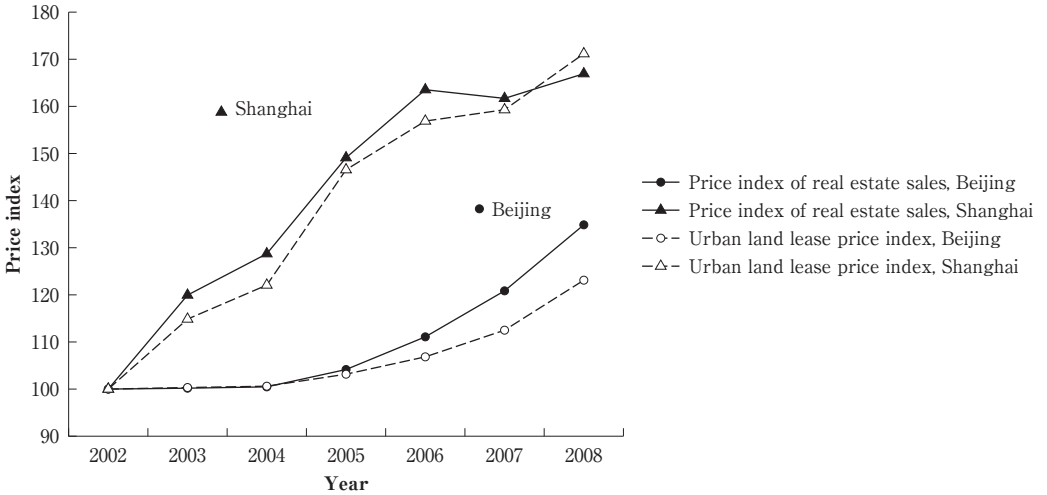

Figure 1. The prices indices of urban land and housing in Beijing and Shanghai

risen in a similar fashion, which suggests a mutual relationship between urban land and housing prices in China. This similarity raised two important questions: What are the determinants of urban land and housing prices in China, and what is the relationship between them.

The related empirical literature has employed two methods to explore the relationship between urban land and housing prices. The first is the Granger causality test. The second uses simultaneous equations. In the first group of studies, Ooi et al. (2006) employed an error correction model to examine causality in housing and land prices in Singapore. Using time-series data from 1990 to 2005, the empirical results of the Granger causality test showed that house and land prices are cointegrated in the long-term, and that housing price changes lead land price changes but not the reverse. Kim et al. (2008) applied the same test to U.S. data from 1985 to 2004 for 27 largest metropolitan statistical areas with a bivariate vector auto-regression model. However, they found that the causality between residential land values and house prices is bidirectional. In the literature regarding the Chinese real estate market, Ai et al. (2008) employed data of Beijing, Shanghai and Wuhan to estimate the relationship between housing and land prices. The estimation results of the Granger causality test demonstrated that an interactive relationship exists between housing and land prices in these cities. Later, using methods and frameworks similar to those of Ooi et al. (2006), Huang et al. (2010) found that, based on data of Chinese 35 cities from 1998 to 2006, land and housing prices have a mutual causal relationship and feedback mechanism. Recently, Du et al. (2011) employed a dataset from Beijing, Shanghai, Tianjin, and Chongqing for the period 2001 to 2009 to examine the impact of land policy on the dynamic relationship between housing and land prices. They found that housing prices are caused by land prices, while the reverse does not hold in the short run.

The literature mentioned above focused on examining the causal relationship between

housing and land prices by using the Granger causality test, but they did not indicate determinants, such as the interest rate, income, population, and so on. To examine the determinants of land and housing prices, the simultaneous equations approach was applied.

In the second group of studies, Potepan (1996) used a two-stage least squares procedure to estimate a three-equation system for major U.S. metropolitan areas from 1974 to 1983. He found that infrastructure quality, property taxes, population size and land-use restrictions matter most in explaining inter-metropolitan variations in housing prices, rents and land prices. Recently, in his analysis of the regional equilibrium of German real estate prices and income, Bischoff (2010) combined Potepan's (1996) model with the spatial equilibrium approach used by Roback (1982) to show the interdependency of housing prices, rental prices, building land prices and income, which used unique cross-sectional data on the major German counties and cities in 2005.

It seems that so far only the U.S. and German real estate markets have been examined by this approach. Moreover, studies using this simultaneous equations approach to investigate the Chinese urban land and housing prices are very few. The only exception is Wen et al. (2010), who utilized the two-stage least squares method to estimate land and housing prices using 21 major Chinese cities for the period 2000 to 2005. Their empirical results showed that endogeneity exists in land and housing prices, on which disposable income has an important impact. Unfortunately, previous studies have not analyzed the impact of the change in the granting methods of land use rights on land prices.

In fact, the Chinese land market has a unique characteristic that there are land use rights which have been separated from land ownership since the 1990s. In other words, the state is now the owner of all urban land, and land users can only possess its use rights. Since local governments are responsible for granting land use rights to users, they can receive revenue from the granting process. There are four ways to grant land use rights: agreement, bidding, auction and listing. Granting through agreement involves negotiation between two actors, land users and the local government. The other three ways adopt the competition mechanism, which was implemented in 2002 to replace the first method. This was an important change in the granting of land use rights in China. It has been pointed out that the power of the local government and the implementation of bidding, auction and listing in the granting of land use rights may result in the increase of land an housing prices, making housing unaffordable for many Chinese citizens (Tian et al., 2009). Has this change in the granting of land use rights significantly affected land and housing prices in China? Further quantitative analyses are needed to deal with this issue. Therefore, this study introduces two variables to represent the characteristics of China's urban land market.

The purpose of the paper is to show the determinants of urban land and housing prices and their relationship in the Chinese context by using urban economic theories and econometric methods. It applies a simultaneous equations approach to analyze a

dataset on 35 major Chinese cities for the period of 2003 to 2008, in which two stage least squares (2SLS) and three stage least squares (3SLS) are used to address the issue of endogeneity. The econometric estimation result shows that land prices and interest rates are important factors affecting housing prices, whereas housing prices and two other factors relating to Chinese land institutions play significant roles in the determination of land prices. These two variables are the extent to which the local government relies on fees for land use rights and the degree of marketization in the granting of land use rights. This empirical evidence indicates that a bidirectional influence between land prices and housing prices in the Chinese urban economy, and that the progress of marketization in the granting of land use rights raises land prices, thereby pushing up housing prices. The evidence also suggests that the reliance of the local government on land-use-right fees contributes to the recent rise in land and housing prices, thus bringing about many social and economic problems in Chinese society.

The remainder of this paper is organized as follows. Section 2 presents a theoretical model. Section 3 describes the estimation model, methods and the data required. Section 4 presents the estimated results of OLS, 2SLS and 3SLS and their related discussions and implications. Section 5 concludes the paper.

2 A Theoretical Model

The essential objective of this paper is to examine the determinants of urban land prices and housing prices in the Chinese context. In this section, using urban economics theories, we present a simple theoretical model of the Chinese real estate market, which consists of both land and housing markets. This section lays the foundation for the estimation in the subsequent sections.

2.1 The Chinese Real Estate Market

Consider that a city consists of several actors, the local government, land users, housing producers and residents. The overall real estate market is assumed to consist of two interrelated sub-markets: the urban land market and the housing market, in which the ownership of housing is transacted. In contrast to Potepan (1996), this model does not include a rental housing market or housing service market.

As mentioned in section 1, the Chinese land market is unique in that it includes a primary market and a secondary market. In the primary market, the state, acting as a landowner, leases land use rights to land users by agreement, listing, auction and bidding. Land users are major players in the secondary market because they develop the land leased from the primary market and build housing on it or re-lease its use rights to other land users (see Tan et al., 2009). The housing producers in the housing market are those land users who gain land use rights from the secondary land market and use land to produce housing for urban residents.

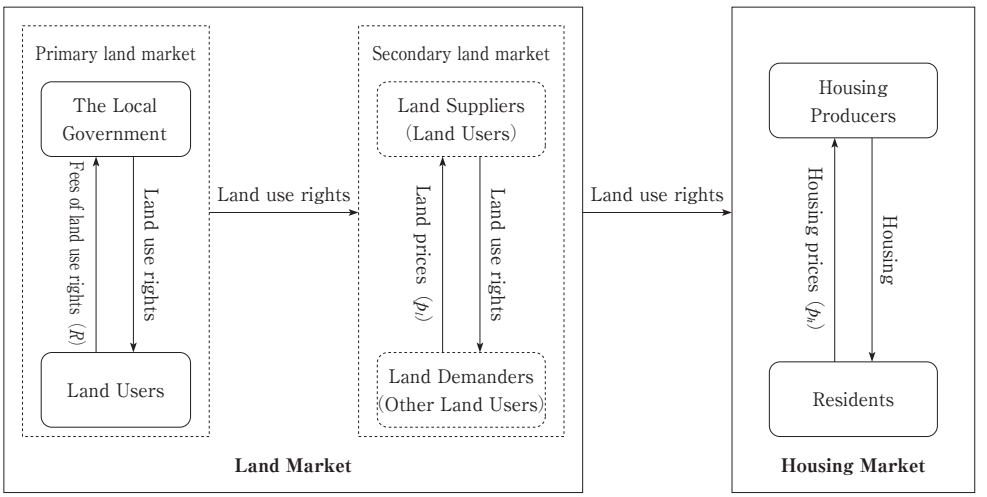

Figure 2. The structure of the Chinese urban land and housing markets

The diagram in Figure 2 shows the structure of the Chinese urban land and housing markets in detail. Since land users in different markets have different roles, land users who re-lease land use rights in the secondary land market are termed land suppliers, and other users in the secondary land market are land demanders. The latter are mainly housing producers that build housing for the housing market.

2.2 Determination of Housing Prices

It is a well-known fact that housing prices are based on modern urban economics (Muth, 1969; Mills, 1972; Henderson, 1985; Fujita, 1989). Hence, the utility function of a representative resident can be written as $U=u(z, h)$, where z is the amount of composite goods and h means the amount of housing consumed. The resident earns a given income, Y, which is spent on the consumption of composite goods and housing. By assuming composite consumer goods as the numeraire, the resident's budget constraint becomes $Y=p_h h+z$, where p_h is the price of housing. Solving the utility maximization problem, we obtain the representative resident's demand function for housing as follows:

$$h^* = h(Y, p_h) \tag{1}$$

If the city's population is given by N, the total demand function for housing can be written as

$$H_d^* = Nh^* = H_d(N, Y, p_h) \tag{2}$$

where H_d is a functional symbol. As for the supply of housing, it can be assumed that the housing producers' aggregate production function of housing for city is given by

$$H_s = f(K_h, L_d) \tag{3}$$

where H_s, K_h and L_d mean the amount of housing produced, capital, and land used,

respectively.

Suppose that the housing producers seek to maximize their profits by choosing proper amounts of capital (K_h) and land (L_d). If there are sufficiently large numbers of such housing developers in the national economy, and the entry into or exit from the city is free, in the long-run equilibrium, their profits could ultimately become zero. As a result, we can formulate the housing producers' demand function for land as follows

$$L_d^* = L_d(p_h,\ p_l,\ i) \tag{4}$$

where L_d is a function symbol, i means the rental of capital K_h and p_l is the price of land used for the production of housing. Meanwhile, the supply function of housing can be written as

$$H_s^* = H_s(p_h,\ p_l,\ i) \tag{5}$$

where L_d is a function symbol. Since the supply of and the demand for housing in the city should be equal, i.e., $H_s^* = H_d^*$, using (2) and (5) the equilibrium price function can be written as

$$p_h = p_h(i,\ p_l,\ N,\ Y) \tag{6}$$

This implies that the resulting housing price (p_h) is a function of the price of land (p_l), personal income (Y), the city's population (N) and the interest rate (i).

2.3 Determination of Land Prices

As mentioned in section 1, the method of granting of land use rights has an effect on land prices. Evidence indicates that the reliance of local governments on the fees from the granting affects the land price in the primary land market (Tian et al., 2009). Meanwhile, the implementation of listing, auction and bidding instead of agreement seems to raise land prices in the primary market. Therefore, for the consideration of land prices, we introduce the following two parameters to reflect these facts. The first one, denoted by λ, is the ratio of the fees of land use rights received by local governments to the total amount of infrastructure investment by local governments, representing the extent to which the local government's public finance relies on the fees for land use rights. The second parameter, denoted by θ, is the ratio of the land area whose use rights are granted through agreement to the total land area granted, which stands for the degree of marketization in the granting of land use rights. In this way, in the primary land market, the unit cost of land use rights leased from the local government can be written as

$$R = R(\lambda,\ \theta) \tag{7}$$

In the secondary market, land users pay R to buy a unit of land use rights from the primary market. We suppose that L_s amounts for land to be used for building housing are produced by l_G amounts of land use rights granted from the local government in the

primary market and amounts of capital, i.e., K_l:

$$L_s = m(K_l,\ l_G) \tag{8}$$

where m is a functional symbol.

These land users select optimal amounts of inputs (K_l and l_G) to maximize their profit. Meanwhile, suppose that there are sufficiently large numbers of land users. In the long-term, their profits should be zero. As a result, we could obtain the supply function of land to the secondary land market as follows

$$L_s^* = L_s(p_l,\ i,\ R) \tag{9}$$

where L_s is a function symbol, i means the rental of capital and R is the unit cost of land use rights granted from local government.

In the secondary land market, the supply of and demand for land should be equal at equilibrium, i.e., $L_s^* = L_d^*$. Using (4) and (9), we could express the resulting price of land as

$$p_l = p_l(p_h,\ i,\ R,) \tag{10}$$

Substituting (7) into (10), land prices could be written as follows:

$$p_l = p_l(p_h,\ i,\ \lambda,\ \theta,) \tag{11}$$

This means that the price of land (p_l) is a function of housing prices (p_h), the interest rate (i), the extent to which the local government relies on the fees of land use rights (λ), and the degree of marketization in the granting of land use rights (θ). It can be confirmed that the price of land (p_l) positively depends on housing prices (p_h). However, the effect of the interest rate on land prices is difficult to determine, since it exists in both the supply and demand functions of land at the same time. As for the degree of marketization in the granting of land use rights (θ), which represented by the ratio of the land area granted through agreement to the total land area granted, a lower θ means a higher marketization degree, which would result in a higher unit cost of land use rights granted in the primary land market. This would cause a higher price of land in the secondary land market (p_l).

Similarly, there would be a positive relationship between land prices (p_l) and the parameter λ, that is, the extent to which the local government relies on the fees of land use rights. In other words, if the local government places greater dependence on the revenue gained from the granting of land use rights, it would have a greater impact on the land granting cost (R) in the primary land market, thus pushing up the land prices in the secondary land market.

In summary, this section describes the Chinese real estate market, which includes land and housing markets. Based on modern urban economic theories, the functions of land and housing prices are derived from land and housing markets, which show the determination mechanism of land and housing prices and the interactive relationship

between these two prices in China's urban economy.

3 Estimation Methods and Data

3.1 The Estimation Model

If we assume that the functions of urban land and housing prices given as Eqs. (6) and (11) in the previous section are log-linear and stochastic, they constitute a simultaneous equations model that can be re-written as follows

$$P_h \equiv \log(p_h) = \alpha_0 + \alpha_1 \log(p_l) + \alpha_2 i + \alpha_3 Y + \alpha_4 N + \varepsilon \quad (12)$$

$$P_l \equiv \log(p_l) = \beta_0 + \beta_1 \log(p_h) + \beta_2 i + \beta_3 \lambda + \beta_4 \theta + \mu \quad (13)$$

where land and housing prices depend upon each other. This simultaneous equations model has two structural equations with two endogenous variables (p_h, p_l) and five exogenous variables (i, Y, N, λ, θ); ε and μ are the error terms. This model will be estimated using a simultaneous equations approach in econometrics and a dataset covering 35 major Chinese cities in the period from 2003 to 2008.

3.2 Estimation Methods

As Gujarati (2003) indicated, in econometric models there is a two-way flow of influence among economic variables; that is, one economic variable affects another economic variable(s) and is, in turn, affected by it (them). In Eqs. (12) and (13), there is a two-way, or simultaneous relationship between p_h and p_l. Since the two variables are jointly determined, the traditional regression potentially is biased. That is, because an increase in the error term of one equation causes an increase in an explanatory variable in the other equation, the assumption of no correlation between the error term and explanatory variables is violated, which leads to biased estimates. Therefore, a simultaneous equation approach is introduced to mitigate this bias.

In this approach, there are two methods: (1)limited information methods, such as two stage least squares (2SLS); (2)full information methods or system methods, such as three stage least squares (3SLS).

In the first method, the basic idea is to replace the stochastic endogenous regressors (which are correlated with the error term and cause the bias) with ones that are non-stochastic and consequently independent of the error term. The following two stages are involves. The first stage is to regress each endogenous variable on all the exogenous variables in the entire system using simple ordinary least squares (OLS) and obtain the fitted value of the endogenous variables. The second is to use the fitted values of endogenous variables and the values of exogenous variables to regress the original equations, which yields consistent estimators. This two-stage method produces consistent estimation, but it is inefficient because the correlation of the cross equations is not taken into account and the exogenous variables from other equations are not used.

The natural extension of 2SLS estimation is the technique of 3SLS, which estimates all of the coefficients of the model to form a weights matrix and then re-estimates the model using the estimated weight matrix. The first two stages of 3SLS are the same as in 2SLS, but its third stage involves the application of feasible generalized least-squares (FGLS) to the equations in the system.

That is, after the coefficients of 2SLS are estimated, the residuals of each equation are used to estimate the cross-equation variances and covariances (the error covariance matrix), which are used to estimate the original system once again. The advantage of the 3SLS procedure is that it takes into account the correlations cross equations and thus improves the large sample efficiency.

3.3 The Data

Our dataset covers 35 major Chinese cities over the period from 2003 to 2008. It coincides with China's recent peak phase of urbanization, private housing market boom and the implementation of new land reforms. These 35 major cities account for one quarter of the total urban population in China. They include four municipalities directly under the central government (Beijing, Shanghai, Tianjin, Chongqing), five cities specifically designated in the state economic plan (Dalian, Ningbo, Xiamen, Shenzhen, Qingdao) and 26 provincial capital cities in China (Shijiazhuang, Taiyuan, Hohhot, Shenyang, Changchun, Harbin, Nanjing, Hangzhou, Hefei, Fuzhou, Nanchang, Jinan, Zhengzhou, Wuhan, Changsha, Guangzhou, Nanning, Haikou, Chengdu, Guiyang, Kunming, Xi'an, Lanzhou, Xining, Yinchuan, Urumqi). Among the four municipalities, Beijing is China's political, educational and cultural center, while Shanghai is the economic and financial center. The cities specifically designated in the state economic plan are all on the coast. Among them, Xiamen and Shenzhen are two of four Special Economic Zones established in the 1980s, and Dalian, Ningbo and Qingdao are coastal harbor cities opened in 1984 by the open-door policy. Among the 26 provincial capital cities, Guangzhou took the lead in establishing the land use rights system and introducing the auction and tender system into the granting of land use rights.

The data used here involves macro-economic indicators as well as real estate market variables. Among them, for housing prices (p_h) and urban land prices (p_l) we use the price index of real estate sales and urban land lease price index, respectively, which are calculated based on the real estate price indices of the 35 major cities in the *China Statistical Yearbook* published by the National Bureau of Statistics.

Concerning Eq. (12), the level of personal income (Y) and the city's population (N) are represented by the data of per capita disposable income and urban registered population, respectively, which are taken from *China City Statistical Yearbook*. Data on the annual interest rate published by the People's Bank of China are used for the interest rate (i) in Eq. (12). In Eq. (13), for the degree of marketization in the granting of land use rights (θ), we use the ratio of the land area the use rights of which are granted through agreements to the total land area granted. These data come from the *China Land and*

Table 1. Variable definitions and descriptive statistics

Variable	Definition	Mean	Standard Deviation
A. Endogenous variables			
P_h	Log of price index of real estate sales	4.762	0.138
P_l	Log of urban land lease price index	4.795	0.218
B. Exogenous variables			
Y	Per capita disposable income (RMB)	13,411.690	4,735.265
N	Total urban registered population (10,000 persons)	285.358	223.928
i	Interest rate	5.504	0.419
λ	Ratio of land-use-right fees to the total amount of infrastructure investment (%)	23.1%	20.6%
θ	Ratio of the land area granted through agreements to the total land area granted (%)	56.7%	26.3%
Air	Index of air pollution	2.454	0.653

Resource Statistical Yearbook complied by the Ministry of Land and Resources. For the extent to which the local government relies on the fees of land use rights (λ), we use the ratio of the fees of land use rights to the total amount of infrastructure investment by the local government, which are calculated from the *China Urban Construction Statistical Yearbook* complied by the Ministry of Housing and Urban-Rural Development. In addition, to examine the robustness of the regressions, we also use the variable of air quality (Air), from the index of air pollution in the *China City Statistical Yearbook* .

Table 1 outlines the symbols and definitions of the variables included in the study, together with their descriptive statistics across the period 2003 to 2008. The grouping of the variables is based on the model specifications. Group A shows the endogenous variables and Group B shows the exogenous variables.

4 Estimated Results

This section first presents the test results regarding the identification of the equation system and the existence of endogeneity in urban land and housing prices. The two tests indicate whether the equation system should be estimated by 2SLS and 3SLS. Second, we estimate our simultaneous equations model by three procedures, OLS, 2SLS and 3SLS. Third, we carry out some diagnostic tests of the validity of the instrumental variables used in 2SLS and 3SLS, and the robustness of estimated results. Finally, we discuss the implications of the estimation results.

4.1 Tests for Identification and Endogeneity

As stated in Section 3, the system of equations in this study consists of two equations, Eqs. (12) and (13), where land prices and housing prices are endogenous variables with five exogenous variables. For this system, the order and rank conditions for the identification

are satisfied, and therefore it can be estimated by 2SLS and 3SLS.

As for endogeneity in the urban land and housing prices, we can use a test proposed by Hausman (1978, 1983). The essential idea of this test is to see whether the regressor in question is correlated with the error term in the equation in which it is assumed an explanatory variable. If so, it is an endogenous variable for which alternatives to OLS must be used. If not, we can use OLS. To perform the test, we first obtain the estimates of land and housing prices by regressing each of them on all exogenous variables. We then estimate their coefficients again by including the resulted residuals as an additional variable (Gujarati, 2003).

The estimated residuals from the equations of housing prices and land prices are −0.36 and 0.38 with their associated t-statistics as −3.99 and 1.62, respectively. This means that the variables of land and housing prices are endogenous at the 10% confidence level, which implies that there is an endogenous problem in the system. Such a problem may lead to estimation bias if OLS is applied. In this case, 2SLS and 3SLS are used to address this problem and to obtain unbiased estimates.

4.2 Estimated Results of OLS, 2SLS and 3SLS

After confirming that the system of equations can be identified and that endogeneity exists in land and housing prices, we apply the methods of 2SLS and 3SLS to estimate Eqs. (12) and (13). The estimated results are summarized in Table 2, where we also present the result of OLS for comparison. As a whole, these results are consistent with those from the theoretical model in Section 2. All of the coefficients have the expected signs, many of which are statistically significant at the 10% level.

For the housing prices equation, the estimated results show that land prices have a positive and significant effect on housing prices. This is consistent with the theoretical result that a higher price of land will reduce the supply of housing, which pushes up the equilibrium housing prices. In other words, a 1% increase in land prices would cause 0.63% of growth in housing prices.

As for the reverse effect of housing prices on land prices in the equation of land prices, it is estimated to be positive with significance at the 10% level by 2SLS and 3SLS. This is also consistent with the theoretical model, suggesting that a higher price of housing would cause the housing producers to demand a great amount of land, which would result in the increase of land prices. By our estimation, a 1% increase in housing prices would make land prices increase by 0.45−0.49%, which is little lower than the estimated effect of land prices on housing prices.

Furthermore, in the housing prices equation, the interest rate has a positive effect on housing prices. This can be interpreted to show that a higher interest rate would increase the cost of producing housing, which reduces the housing supply and results in higher equilibrium housing prices. Meanwhile, disposable income and the city's population are both positive with a statistical significance at the 5% level by 3SLS, which is also consistent with the theoretical expectation. That is, both would increase the demand for

Table 2. Estimated results of OLS, 2SLS and 3SLS

Variable	OLS	2SLS	3SLS
For housing prices equation			
Log of urban land lease price index (P_l)	0.324*** (0.034)	0.625*** (0.100)	0.633*** (0.099)
Interest rate (i)	0.077*** (0.018)	0.039* (0.024)	0.036* (0.037)
Per capita disposable income (Y)	3.58E-07 (2.55E-07)	1.44E-07 (3.07E-07)	4.26E-07** (2.38E-07)
Total urban registered population (N)	0.00013*** (3.24E-05)	0.000125** (3.82E-05)	9.51E-05*** (3.22E-05)
R-squared	0.465	0.258	0.242
For land prices equation			
Log of price index of real estate sales (P_h)	0.784*** (0.103)	0.451* (0.312)	0.498* (0.307)
Interest rate (i)	0.006 (0.031)	0.039 (0.043)	0.039 (0.043)
The extent to which the local government relies on land-use-right fees (λ)	0.134** (0.061)	0.170** (0.070)	0.112** (0.054)
The marketization degree in the granting of land use rights (θ)	−0.102** (0.050)	−0.157** (0.071)	−0.182*** (0.067)
R-squared	0.383	0.351	0.356

Notes: (1)The numbers in parentheses are standard errors.
(2)***denotes significance at 1%; **denotes significance at 5%; *denotes significance at 10%.

housing, which then raises housing prices.

On the other hand, in the land prices equation, the interest rate is involved in both supply and demand sides, so it is difficult to predict theoretically the sign of its estimate. Table 2 shows that we found that the estimate of the interest rate is not statistically significant, which suggests that its effects on land prices may be offset in the balance of supply and demand. Regarding the effects of θ introduced in the theoretical model, theoretically, a lower θ represents a higher degree of marketization in the granting of land use rights, which would result in a higher cost of land use rights leased in the primary land market. This also means a higher cost for the land users in the secondary land market, which leads to higher land prices. Table 2 indicates that the estimate of θ is negative and statistically significant at the 5% level. This confirms the above theoretical arguments regarding the effect of θ. Finally, looking at the variable (λ) appearing in the land prices equation, Table 2 shows that its estimate is positive and significant at the 5% level, which is consistent with the expected result from the theoretical model. That is, the extent to which the local government relies on the land revenue obtained from the granting of land use rights has a positive effect on the land prices in the Chinese urban economy.

4.3 Diagnostic Tests

To obtain the above estimated results by 2SLS and 3SLS, all the exogenous variables in the system are used as the instruments. About the validity of these instruments, we apply the Sargan test (Sargan, 1964) to check. The null hypothesis of the Sargan test is

Table 3. Tests on the robustness of estimation

Variable	2SLS		3SLS	
	without *Air*	with *Air*	without *Air*	with *Air*
For housing prices equation				
Log of urban land lease price index (P_l)	0.625*** (0.100)	0.607*** (0.100)	0.633*** (0.099)	0.617*** (0.098)
Interest rate (i)	0.039* (0.024)	0.039* (0.023)	0.036* (0.037)	0.037* (0.023)
Per capita disposable income (Y)	1.44E-07 (3.07E-07)	7.18E-08 (3.06E-07)	4.26E-07** (2.38E-07)	3.58E-07* (2.32E-07)
Total urban registered population (N)	0.00013** (3.82E-05)	0.00014*** (3.96E-05)	9.5E-05*** (3.22E-05)	0.00011*** (3.40E-05)
The index of air pollution (Air)	——	−0.0167 (0.014)	——	−0.015* (0.010)
R-squared	0.258	0.288	0.242	0.270
For land prices equation				
Log of price index of real estate sales (P_h)	0.451* (0.312)	0.444* (0.300)	0.498* (0.307)	0.477* (0.295)
Interest rate (i)	0.039 (0.043)	0.039 (0.042)	0.039 (0.043)	0.041 (0.042)
The extent to which the local government relies on land-use-right fees (λ)	0.170** (0.070)	0.171** (0.070)	0.112** (0.054)	0.117** (0.055)
The marketization degree in the granting of land use rights (θ)	−0.157** (0.071)	−0.158** (0.069)	−0.182*** (0.067)	−0.184** (0.065)
R-squared	0.351	0.350	0.356	0.353

Notes: (1) The numbers in parentheses are standard errors.
(2) *** denotes significance at 1%; ** denotes significance at 5%; * denotes significance at 10%.

that all instruments used are valid. If the computed chi-square exceeds the critical chi-square value, we reject the null hypothesis, which means that at least one instrument is correlated with the error term and the estimation based on the chosen instruments is not valid (Gujarati, 2003). By calculation, the chi-squares of the land prices and housing prices equations are 2.412 and 2.056, respectively. Both are less than the 5% critical value in the chi-square distribution with one degree of freedom, 3.841, so we could accept the null hypothesis that all instruments are valid.

Meanwhile, in order to check the robustness of the estimation results reported above, we regress the equation system again by adding one more exogenous variable. As in Zheng et al. (2010), we choose the index of urban air pollution (Air) as the exogenous variable. Table 3 presents the estimated results of 2SLS and 3SLS with and without this variable.

Table 3 shows that in the housing prices equation, the coefficients involved do not change very much after introducing this additional variable into the equation. The estimated result by 3SLS also indicates that air pollution is negatively correlated with housing prices at the significant level of 10%, which is consistent with common sense.

For the land prices equation, the coefficients included also are little changed after adding this variable. Therefore, we can conclude that the original estimation results are robust to small changes in the different variables chosen and estimation methods used.

4.4 Implications of Estimated Results

The above estimated results of the simultaneous equations approach provide several interesting findings. First, we found that land prices are an important factor in housing prices, while housing prices also play a significant role in the determination of land prices. That is, there is a considerable two-way influence between land prices and housing prices in China's major cities. This result is similar to Potepan (1996), who pointed out that an endogenous interplay exists between housing prices and land prices in the U.S. housing market. Table 2 also shows that the estimated coefficients involved in using 2SLS and 3SLS are different from those obtained from OLS. Moreover, 2SLS and 3SLS seem to have addressed the issue of endogneity in land and housing prices, which results in biased estimation when using OLS.

Second, Potepan's empirical results indicated that mortgage interest rates have no significant effect on housing prices in the U.S. However, our estimated results for the interest rate in the housing prices equation demonstrate that interest rates have a positive effect on housing prices, which is consistent with other empirical studies on the Chinese context, such as Du et al. (2010). In fact, changes in the interest rate could affect bank loans. The increasing cost of bank lending is closely related to property-related investments, thus leading to a rise in housing prices. This result also implies that macro-monetary policies play a great role in the current Chinese urbaneconomy.

Finally, regarding the two important variables (λ and θ) introduced to reflect the effects of the granting system of land use rights, we have shown that the signs of their estimated coefficients are consistent with the expectation from the theoretical model. This indicates that, on one hand, the current Chinese system of granting land use rights seriously affects the determination of land prices, thereby influencing land prices indirectly. On the other hand, it also implies that the need for local governments to increase their local revenue for infrastructure investment through the granting of land use rights also causes increasing land prices, which pushes up housing prices because of the bidirectional relationship between land and housing prices. Although the revenue from the granting by market-oriented methods does contribute to the improvement of infrastructure and local public services, over-reliance on it would cause land prices to soar, leading to further loss of cultivated land and making housing unaffordable for middle and low-income households. Furthermore, as Peterson (2006) pointed out, the local government's reliance on land sales would create the fiscal risk in that municipalities would become too dependent upon asset sales for covering recurring costs. In the event that the assets became unavailable, they would face an even more severe budget shortfall and would need the help of the national government. Although China has implemented some market-oriented reforms in its urban real estate market, there remain many features of statism, such as the ownership of urban land by the state. The government, therefore, has a long and arduous road to make the real estate market more effective and efficient.

5 Conclusions

This paper applied a simultaneous equations approach to study the determinants of urban land and housing prices in China and the relationship between them, using modern urban economics as the theoretical basis and a dataset from 35 major Chinese cities in period 2003 to 2008 for empirical estimation. The study uses 2SLS and 3SLS to address the issue of endogeneity in land and housing prices and to mitigate the bias in OLS estimation. The estimated results show that land prices significantly affect housing prices, while housing prices play an important role in the determination of land prices, which indicates a bidirectional influence between land prices and housing prices in China's major cities. The study found that the interest rate has a positive impact on housing prices, which then affects land prices. In the determination of land prices, two variables are significant. They represent the extent to which the local government relies on the fees of land use rights and the degree of marketization in the granting of land use rights, which reflects the characteristics of the current Chinese real estate market system. This paper also discussed some implications of these empirical results regarding the development of the Chinese real estate market. Although the revenue from the granting of land use rights by market-oriented methods does contribute to the improvement of infrastructure construction and local public services, over-reliance on it would lead to increasing land prices, pushing up housing prices and making housing unaffordable for middle and low-income households. This paper is the first step to study the effect of the Chinese land granting system on land and housing prices using a simultaneous equations approach. We believe that this is useful for us to understand the land and housing markets in the current Chinese urban economy.

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