Determination of Urban Land and Housing Prices in Japan from 1990 to 2009*

Lei WU
Xiao-Ping ZHENG

Abstract

Using urban economic theories, this paper studies the determinants of urban land and housing prices in Japan and estimates them by a simultaneous equations approach in which 2SLS and 3SLS are used to address the issue of endogeneity. Using a dataset on 10 urban prefectures over the period from 1990 to 2009, the results of our econometric estimation show that land prices significantly affect housing prices, while housing prices also play an important role in the determination of land prices. The findings also show that housing prices depend on not only fundamental factors, such as the size of population, real income per capita, and construction prices, but also on the user cost related to property tax and the expected growth rate of housing prices. Meanwhile, agricultural land prices, construction prices, and the property tax rate on land are found to have significant effects on land prices. This empirical evidence indicates that there is also a bidirectional influence between land prices and housing prices in Japan's major urban prefectures. It also implies that the implementation of a property tax on housing could contribute to the control of housing prices. Furthermore, an effective property tax system on land would be useful to restrain excessive demands for residential land.

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

1 Introduction

In the 1980s, Japan experienced a dramatic rise and fall in land and housing prices. In 1983, asset prices began increasing, and the resulting bubble collapsed in the late 1980s. The literature of the 1990s showed that the high prices in Japan during the 1980s resulted mainly from government policies, including the tax system and the land lease law, which distorted land use. In addition, expansionary money policy was a major cause of the sharp increases in land price (Kanemoto, 1997). Since the share of land purchase cost in the total housing cost is high — over 60 percent in Japanese larger cities — the housing problem is

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almost synonymous with the land problem or land price problem. It has also been shown that housing prices are relatively high in Japan, which is due in large part to the much higher price of land. The current evidence shows that housing consumption usually comprises 20% or more of a household's budget, making it the single most important budget item (Borsch-Supan et al., 2001), which suggests that housing plays a key role in a household's consumption. However, aside from land prices, what are other determinants of housing prices, and what impact did the tax system have on housing and land prices after the bubble ?

A substantial number of studies have focused on the determinants of land prices or housing prices in Japan since the collapse of asset prices bubble in the late 1980s. With respect to the recent literature, in recent research on housing prices, Seko (2004) explored the dynamics of regional real house prices by estimating serial correlation and mean reversion coefficients from the panel data of 46 prefectures in the period from 1980 to 2002 in Japan. The results showed that housing prices reacted differently to economic shocks, depending on such factors as population size, income growth, construction costs, and real user costs. On the other hand, Nakamura et al. (2003) analyzed the determinants of newly built condominium prices from the perspective of supply. They applied two-stage least squares to a single equation using a dataset of Tokyo's metropolitan area for the period from 1974 to 2001, and concluded that the inventory ratio of stock housing and economic trends have negative and positive effects on the prices of newly built condominiums, respectively.

Regarding the determinants of land prices, the main concern of previous studies was the relationship between economic fundamentals and land price indicators. Based on an error-correction analysis, Nakamura et al. (2007) found that not only changes in the discounted present value of land were related to the income level, the expected growth of future income, interest rates, tax rates, and risk premiums but also changes in the demographic factor and bank lending influenced the fluctuations of real land prices. Kamada et al. (2007) also showed that land prices have always been determined by economic fundamentals, such as population growth, income per capita, and the availability of funds. More importantly, although they found no robust evidence to support the idea that land prices have become more sensitive to economic fundamentals since the asset bubble burst in the early 1990s in the 47 prefectures of Japan; however, evidence does exist for the 23 wards in Tokyo.

Previous empirical studies on Japanese real estate market emphasized the estimation of a single equation for either housing prices or land prices. Very few empirical studies have explored how both land prices and housing prices were determined using a simultaneous equation approach to address the issue of simultaneity or endogeneity. Among them, Potepan (1996) used a two-stage least squares procedure to estimate a three-equation system about the major U. S. metropolitan areas from 1974 to 1983. He found that infrastructure quality, property taxes, population size, and land-use restrictions matter the most in explaining the inter-metropolitan variations in housing prices, rents, and land prices. Recently, in an analysis of the regional equilibrium of German real estate prices and income, Bischoff (2010) combined Potepan's (1996) model with a spatial equilibrium approach to show interdependency among housing prices, rental prices, building land prices, and income, using unique cross-sectional data on the major German counties and cities in 2005.

Thus, so far only the U. S. and German real estate markets have been examined using the simultaneous equations model. There have been no comparable studies in Japan. This paper is the first empirical study on the determination of housing and land prices to use the simultaneous equation approach. Our study used a dataset on 10 urban prefectures in Japan over the period from 1990 to 2009. The results of our econometric estimation show that land prices significantly affect housing prices, whereas housing prices also play an important role in the determination of land prices, which indicates that there is also a bidirectional influence between land prices and housing prices in major Japanese prefectures. We also found that housing prices depend on not only fundamental factors such as the size of population, after-tax income, and construction prices but also user costs related to the property tax rate, the expected growth rate of housing prices, and interest rates. One implication is that the implementation of property taxes on housing could contribute to the control of housing prices. We also found that agricultural land prices, construction prices, and land tax rates have significant effects on land prices. We therefore suggest that an effective property tax system on land could influence the use and sale of land and would be useful to restrain an excessive demand for residential land.

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

2 A Theoretical Model

In this section, we apply urban economic theories to present a simple theoretical model of the Japanese real estate market, which consists of both land and housing markets. This section lays the foundation for the estimation model presented in section 3.

2.1 The Japanese Real Estate Market

The Japanese real estate market involves several economic actors, including land suppliers and demanders, and housing suppliers (producers) and demanders (residents). This market can be assumed to consist of two interrelated sub-markets: the urban land market and the housing market. Figure 1 shows the basic structure of the urban land and housing markets. Land suppliers are landowners who obtain land from agricultural landowners, and sell or rent it to a land demander. Land demanders are land users in the land market who are also housing suppliers in the housing market. Housing producers use land

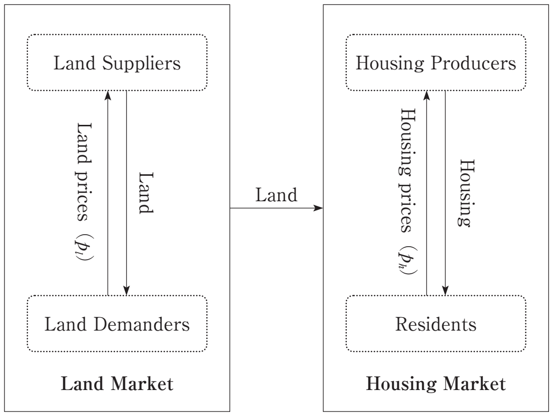

Figure 1. The structure of the Japanese urban land and housing markets

purchased from the land market to produce housing for urban residents, that is, housing demanders.

2.2 Determination of Housing Prices

We can apply modern urban economics (Muth, 1969; Mills, 1972; Henderson, 1985; Fujita, 1989) to express the housing prices determined by the housing market (Figure 1). More specifically, we also use Seko's (2006) theory of housing demand in Japan. Suppose that a city is composed of N residents and housing firms. The utility function of a representative resident can be written as $U = \alpha \ln z + \beta \ln h$, where h means the amount of housing consumed and z is the amount of other goods with the exception of housing; α and β are positive parameters satisfying $\alpha + \beta = 1$. By assuming composite consumer goods as the numeraire and the after-tax income of a resident as Y, the resident's budget constraint can be written as, $Y = p_h u_c h + z$, where p_h is the unit price of housing and $p_h u_c$ is the user cost of capital for owner-occupied housing. Suppose that the resident needs to maximize his or her utility by choosing an amount of goods and housing. Such a maximization problem can be written as

$$\underset{\langle z,h \rangle}{Max} \quad U = \alpha \ln z + \beta \ln h \tag{1}$$

$$s.\ t. \quad Y = p_h u_c h + z \tag{2}$$

In the early 1980s, a more precise definition of the user cost of homeownership was incorporated into the theory of housing demand (Kearl, 1979; Poterba, 1984). Himmelberg et al. (2005) pointed out that user cost is equal to one year's cost of owning a house. The financial return associated with an owner-occupied housing property compares the value of living in that property with the lost income that one would have received if the owner had invested the capital in an alternative investment. This comparison should take into account differences in risk, tax benefits from owner-occupancy, property taxes, maintenance expenses, and any anticipated capital gains from owning the home. In this paper, the formula of the user cost of capital for owner-occupied housing is based on Seko (2006) and is expressed as follows:

$$p_h u_c = (i + t_h - e) p_h \tag{3}$$

where i is the nominal interest rate (which is assumed to equal the rate of return on other assets), e is the expected growth rate of housing prices, and t_h is housing property tax rate. This means that the user cost in Japan involves the costs of home ownership, which consists of the interest rate, the expected growth rate of housing prices, and the property tax rate on housing. It also reflects the fact that neither mortgage interest payments nor local property taxes are tax-deductible and most income from non-housing assets is tax tempt.

Substituting Eq. (3) into Eq. (2), the first-order conditions of the maximization problem give

$$h^* = \beta \frac{Y}{p_h(i + t_h - e)} \tag{4}$$

$$z^* = \alpha Y \tag{5}$$

Thus, the total demand for housing H_d^* in the city can be written as

$$H_d^* = Nh^* = \beta \frac{NY}{p_h(i + t_h - e)} \tag{6}$$

Concerning the supply of housing, it is assumed that the aggregate production function of the city's housing firms is given by

$$H_s = A L_d^a S^b K_h^c \tag{7}$$

where H_s is the amount of housing produced, and L_d, K_h and S are the amounts of land, capital and other construction materials used, respectively. A, a, b and c are positive parameters, and $0 < a + b + c < 1$.

The total cost of housing production can be written as

$$C_h = p_l L_d + p_s S + i K_h \tag{8}$$

where p_l is the price of land, i is the rental of capital (i.e., the nominal interest rate), and p_s is the price of other construction materials.

Suppose that the housing firms seek to minimize the total cost by choosing proper amounts of land (L_d), capital (K_h), and other construction materials (S), which can be expressed as

$$\underset{\langle L_d, S, K_h \rangle}{Min} \quad C_h = p_l L_d + p_s S + i K_h \tag{9}$$

$$s.\ t. \quad H_s = A L_d^a S^b K_h^c \tag{10}$$

The first-order conditions of this minimization problem yield

$$\frac{i}{p_l}=\frac{cL_d}{aK_h} \tag{11}$$

$$\frac{p_l}{p_s}=\frac{aS}{bL_d} \tag{12}$$

Suppose that there are sufficiently large numbers of such housing firms in the national economy and that the entry into (or exit from) the city is free. Thus, in long-run equilibrium, the profit of housing firms could ultimately become zero. Hence, we can obtain the following demand functions of land, capital, and other construction materials.

$$L_d^*=\left[\frac{Aa^{1-b-c}b^bc^c}{(a+b+c)}\right]^{\frac{1}{(1-a-b-c)}}\left(\frac{p_h}{p_l^{1-b-c}p_s^bi^c}\right)^{\frac{1}{(1-a-b-c)}} \tag{13}$$

$$S^*=\left[\frac{Aa^ab^{1-a-c}c^c}{(a+b+c)}\right]^{\frac{1}{(1-a-b-c)}}\left(\frac{p_h}{p_l^ap_s^{1-a-c}i^c}\right)^{\frac{1}{(1-a-b-c)}} \tag{14}$$

$$K_h^*=\left[\frac{Aa^ab^bc^{1-a-b}}{(a+b+c)}\right]^{\frac{1}{(1-a-b-c)}}\left(\frac{p_h}{p_l^ap_s^bi^{1-a-b}}\right)^{\frac{1}{(1-a-b-c)}} \tag{15}$$

Substituting Eqs. (13), (14) and (15) into Eq. (7), the aggregate supply function of housing in the city can be written as

$$H_s^*=\left[\frac{Aa^ab^bc^c}{(a+b+c)^{a+b+c}}\right]^{\frac{1}{(1-a-b-c)}}\left(\frac{p_h^{a+b+c}}{p_l^ap_s^bi^c}\right)^{\frac{1}{(1-a-b-c)}} \tag{16}$$

Since the supply of and the demand for housing in the city should be equal, (i.e., $H_d^*=H_s^*$), the equilibrium price of housing can be obtained using Eqs. (6) and (16) as follows:

$$p_h=\frac{\alpha^{1-a-b-c}(a+b+c)^{a+b+c}}{Aa^ab^bc^c}\frac{(NY)^{1-a-b-c}p_l^ap_s^bi^c}{i+t_h-e} \tag{17}$$

Eq. (17) implies that the equilibrium housing price (p_h) is an increasing function of the price of land (p_l), the price of other construction materials (p_s), personal income (Y), and the city's total population (N). Eq. (17) also indicates that an increase in the property tax rate on housing (t_h) or a decrease in the expected growth rate of housing prices (e) would raise the user cost of housing and then decrease housing prices. The effect of the interest rate (i) on housing prices is indeterminable, because it exists in both the supply and demand functions of housing at the same time.

2.3 Determination of Land Prices

Concerning the land market as shown in Figure 1, we suppose that urban land is produced from the inputs of agricultural land and capital as follows:

$$L_s=BK_l{}^ml_{ag}{}^n \tag{18}$$

where L_s is the amount of urban land developed, and K_l and l_{ag} indicate the amounts of capital and agricultural land used, respectively; B, m and n are positive parameters, and $0<m+n<1$.

The total cost of developing urban land can be written as

$$C_l = iK_l + p_{ag} l_{ag} \tag{19}$$

where i is the rental of capital (i.e., the nominal interest rate) and p_{ag} is the price of agricultural land.

Suppose that urban land developers (suppliers) select proper amounts of inputs (K_l and l_{ag}) to minimize the total cost, which can be written as:

$$\underset{\langle K_l, l_{ag} \rangle}{Min} \quad C_l = iK_l + p_{ag} l_{ag} \tag{20}$$

$$s.t. \quad L_s = BK_l{}^m l_{ag}{}^n \tag{21}$$

Meanwhile, suppose that there are sufficiently large numbers of land developers in the national economy. The profits after the land property tax can be expressed as

$$\pi_l = p_l(1-t_l)L_s - (iK_l + p_{ag} l_{ag}) \tag{22}$$

where t_l means the rate of property tax on urban land.

In the long term, the profits of urban land developers should be zero. Thus, we could obtain the supply functions of agricultural land and capital as follows:

$$l_{ag}^* = \left[\frac{Bm^m n^{1-m}}{(m+n)}\right]^{\frac{1}{(1-m-n)}} \left(\frac{p_l(1-t_l)}{i^m p_{ag}{}^{1-m}}\right)^{\frac{1}{(1-m-n)}} \tag{23}$$

$$K_l^* = \left[\frac{Bm^{1-n} n^n}{(m+n)}\right]^{\frac{1}{(1-m-n)}} \left(\frac{p_l(1-t_l)}{i^{1-n} p_{ag}{}^n}\right)^{\frac{1}{(1-m-n)}} \tag{24}$$

Substituting Eqs. (23) and (24) into Eq. (18), the supply function of urban land in the city can be written as

$$L_s^* = \left[\frac{Bm^m n^n}{(m+n)^{m+n}}\right]^{\frac{1}{(1-m-n)}} \left\{\frac{[p_l(1-t_l)]^{m+n}}{i^m p_{ag}{}^n}\right\}^{\frac{1}{(1-m-n)}} \tag{25}$$

Since the supply of and the demand for urban land in the city should be equal, (i.e., $L_d^* = L_s^*$), using Eqs. (13) and (25), the equilibrium price of urban land is obtained as follows

$$p_l = E\left\{\left(\frac{p_h}{p_s^b}\right)^{\frac{1}{(1-a-b-c)}} \left[\frac{p_{ag}^n}{(1-t_l)^{m+n}}\right]^{\frac{1}{(1-m-n)}} i^{\left(\frac{m}{1-m-n} - \frac{c}{1-a-b-c}\right)}\right\}^{\frac{(1-a-b-c)(1-m-n)}{(1-a-b-c)(m+n)+(1-b-c)(1-m-n)}} \tag{26}$$

where E is a positive parameter.

Hence, the equilibrium price of urban land (p_l) is a function of housing prices (p_h), the price of agricultural land (p_{ag}), the rental of capital (i), the price of other construction materials (p_s), and the rate of property tax on land (t_l). It can be confirmed that the price of land (p_l) positively depends on p_h, p_{ag}, and t_l, and is negatively related to p_s. However, the effect of the interest rate on land prices is indeterminable, since it exists in both the supply and demand functions of land at the same time.

In summary, this section presents a theoretical model and describes the Japanese real estate market, which includes urban land and housing markets. Based on modern urban economic theories, the functions of urban land and housing prices are derived from urban land and housing markets to show the determination mechanism of urban land and housing prices.

3 Estimation Methods and Data

3.1 The Estimation Model

In order to verify the theoretical results of the previous section empirically, we assume that the functions of urban housing and land prices Eqs. (17) and (26) can be expressed as log-linear and stochastic, thus constituting a simultaneous equations system as follows:

$$\log(p_h)=\alpha_0+\alpha_1\log(p_l)+\alpha_2\log(N)+\alpha_3\log(Y)+\alpha_4\log(p_s)+\alpha_5\log(i) \\ +\alpha_6\log(t_h)+\alpha_7\log(e)+\varepsilon \tag{27}$$

$$\log(p_l)=\beta_0+\beta_1\log(p_h)+\beta_2\log(p_{ag})+\beta_3\log(i)+\beta_4\log(p_s)+\log(t_l)+\mu \tag{28}$$

This simultaneous equations system has two structural equations with two endogenous variables (p_h, p_l), and eight exogenous variables (p_s, i, Y, N, t_h, e, p_{ag}, and t_l); ε and μ are the error terms. This system can be estimated using the simultaneous equations approach in econometrics.

3.2 Estimation Methods

In Eqs. (27) and (28), there is a two-way, or simultaneous, relationship between p_h and p_l. Since the two variables are jointly determined, the traditional regression method is potentially 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, thus leading to biased estimates. Therefore, a simultaneous equation approach is needed to mitigate this bias.

Two methods are used in this approach: (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 regressors that are non-stochastic and consequently independent of the error term. The following two stages are involved. The first stage is to regress each endogenous variable on all the exogenous variables in the entire system using simple ordinary least squares (OLS) to 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 correlations of the cross equations are 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 then used to estimate the original system once again. The advantage of the 3SLS procedure is that it takes into account the cross-correlation equations and thus improves the large sample efficiency.

In addition, the generalized method of moments (GMM) introduced by Hansen (1982) is also applied to estimate the simultaneous equations model in order to check the robustness of the estimation results. Wooldridge (2001) pointed out that if heteroskedasticity or unobserved effects models are present, a generalized method of moments can give better results when it is applied to panel data. Implementing GMM is straightforward. As in 2SLS, one needs to specify the dependent variable, explanatory variables, and exogenous variables (including the instruments). The only difference from 2SLS is the use of the efficient weighting matrix that accounts for possible heteroskedasticity.

3.3 The Data

The dataset used in this study covers two main metropolitan areas across 10 prefectures in Japan over the period from 1990 to 2009. The two main metropolitan areas are Tokyo, which includes the Metropolis of Tokyo and the Prefectures of Kanagawa, Saitama and Chiba, and Osaka, which comprises the Prefectures of Osaka, Kyoto, Hyogo, Nara, Shiga and Wakayama.

The data used here include macro-economic indicators as well as real estate market variables. For housing prices (p_h), we use the average sale prices of newly built condominiums, which are taken from *Japanese Real Estate Statistics*. Urban land prices (p_l) are represented by the average prices of residential land, which are listed in the *Japan Statistical Yearbook*.

Concerning Eq. (27), we obtain the price of other construction materials (p_s) by dividing total construction costs for condominiums by total floor space. These data are taken from the *Construction Statistics Yearbook* by the Ministry of Land, Infrastructure and Transport. The rate of property tax on housing (t_h) is represented by the ratio of per unit property tax on housing (reinforced concrete structures) to per unit price of new-built condominiums. These data are from the *Summary Report on Prices, etc. of Fixed Assets* (*Land*). The level of prefectural per capita income (Y) and population (N) are taken from *Annual Report on Prefectural Accounts* and *Japan Statistical Yearbook*. The data on average interest rates for loans and discounts of domestic banks in the *Finance and Economic Statistics Monthly* by the Bank of Japan are used as the interest rate (i). For the expected growth rate of housing prices (e), we use the annual average rate of adjusted regional index of consumer prices. These data are taken from the *Japan Statistical Yearbook*.

Table 1. Variable definitions and descriptive statistics

Variables	Definition	Mean	Standard Deviation
A. Endogenous variables			
p_h	Average sale prices of new-built condominiums (10,000 yen/m^2)	51.213	15.683
p_l	Average prices of residential land (10,000 yen/m^2)	17.707	12.706
B. Exogenous variables			
p_s	Construction prices (10,000 yen/m^2)	18.569	3.256
Y	Prefectural per capita income (10,000 yen)	314.565	47.049
N	Prefectural population (10,000 persons)	534.078	351.844
i	Interest rate	3.041	1.768
t_h	Ratio of per unit property tax on housing to per unit price of new-built condominiums.	0.240	0.114
e	Average rate of adjusted regional consumer prices index	1.331	0.394
t_l	Ratio of per unit property tax on residential land to per unit price of residential land	0.355	0.162
p_{ag}	Prices of paddy fields and fields converted to residential land (10,000 yen/m^2)	13.486	7.801

Regarding Eq. (28), the rate of property tax on land (t_l) is represented by the ratio of per unit property tax on residential land to per unit price of residential land. The data are taken from the *Summary Report on Prices, etc. of Fixed Assets* (*Land*). The agricultural land price (p_{ag}) are the prices of paddy fields and fields converted to residential land, which are taken from the *Japan Statistical Yearbook*.

Table 1 outlines the symbols and definitions of the variables included in the study, together with their descriptive statistics across the period 1990 to 2009. 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

In this section, we first present the test results regarding the identification of the equation system and the existence of endogeneity in urban land and housing prices. The results suggest that the equation system could be estimated by 2SLS and 3SLS. Second, we estimate our simultaneous equations model by two procedures, 2SLS and 3SLS. Third, we carry out diagnostic tests regarding the validity of the instrumental variables and the robustness of estimated results. Finally, we discuss the implications of the estimated results.

4.1 Tests for Identification and Endogeneity

Section 3 demonstrates that the system of equations in this study consists of two equations, Eqs. (27) and (28), in which land prices and housing prices are endogenous variables with several exogenous variables. In this system, the order and rank conditions for the over-identification are satisfied, and therefore it can be estimated by 2SLS and 3SLS.

As for the endogeneity of urban land and housing prices, we can use the 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. 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 resulting residuals as an additional variable (Gujarati, 2003).

The estimated residuals from the equations of housing prices and land prices are 0.564 and −0.166 with associated t-statistics at 6.373 and −2.145, respectively. This means that the variables of land and housing prices are endogenous at the 5% 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 could be used to address this problem and obtain unbiased estimates.

4.2 Estimated Results

Since the system of equations can be identified, and endogeneity exists in land and housing prices, we apply the methods of 2SLS and 3SLS to estimate Eqs. (27) and (28). The estimated results are summarized in Table 2. The results are generally consistent with those in the theoretical model given in Section 2. All 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, which is consistent with the theoretical result that higher prices of land will reduce the supply of housing, pushing up the equilibrium in housing prices. In other words, a 1% increase in land prices would cause 0.43% 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 1% 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 large 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 about 0.59%.

Furthermore, with respect to the effect of interest rates on the housing prices equation, according to the theoretical model, a higher interest rate would increase the user cost and reduce housing demand. This would result in a lower equilibrium housing prices. However, on the supply side of housing, a higher interest rate would increase the cost of producing

Table 2. Estimated results of 2SLS and 3SLS

Variables	2SLS	3SLS
For housing prices equation		
Average prices of residential land (p_l)	0.443*** (0.084)	0.433*** (0.082)
Construction prices (p_s)	1.073*** (0.177)	1.095*** (0.175)
Interest rate (i)	0.254*** (0.041)	0.258*** (0.040)
Prefectural per capita income (Y)	0.234*** (0.118)	0.274*** (0.115)
Prefectural population (N)	0.0007*** (0.0002)	0.0007*** (0.0002)
Ratio of per unit property tax on housing to per unit price of new-built condominiums (t_h)	−1.002*** (0.340)	−0.888*** (0.330)
Average rate of adjusted regional consumer prices index (e)	0.062* (0.036)	0.059* (0.035)
R-squared	0.924	0.923
For land prices equation		
Average sale prices of new-built condominiums (p_h)	0.594*** (0.089)	0.588*** (0.087)
Construction prices (p_s)	−0.490*** (0.169)	−0.487*** (0.167)
Interest rate (i)	−0.030 (0.029)	−0.030 (0.028)
Prices of paddy fields and fields converted to residential land (p_{ag})	0.067*** (0.008)	0.067*** (0.008)
Ratio of per unit property tax on residential land to per unit price of residential land (t_l)	0.482*** (0.190)	0.450*** (0.184)
R-squared	0.950	0.950
Observations	200	200

housing, which reduces the housing supply and results in higher equilibrium housing prices. By our estimation, the interest rate has a positive effect on housing prices. This suggests that the impact of interest rate on the supply side of housing is more important than that on the demand side of housing in Japan. Meanwhile, prefectural per capita income and population have positive effects on housing prices with a statistical significance at the 1% level by 3SLS, which is also consistent with the theoretical expectation. That is, income and population would increase the demand for housing and then raise housing prices.

Last but not least, regarding the effects of the rate of property tax on housing (t_h) and the expected growth rate of housing prices (e), according to the theoretical model, a higher property tax rate or a lower the expected growth rate of housing prices would cause reduce the demand for housing and then decrease the equilibrium housing prices. Table 2 indicates that the estimates of property tax rate on housing (t_h) and expected growth rate of housing prices (e) are significantly, respectively, which is consistent with the theoretical arguments.

The variable measuring construction prices appears in both the housing prices and land prices equations. The theoretical model predicts that higher construction prices would cause higher cost of housing production, thereby increasing the equilibrium housing prices. Meanwhile, higher cost in housing production would make housing producers to demand less urban land, and then reduce the equilibrium land prices. The results in Table 2 are consistent with this theoretical prediction. That is, the effect of construction prices is positive on housing prices, but negative on land prices.

For the land prices equation, regarding the effect of agricultural land prices (l_{ag}), theoretically, higher agricultural land prices would result in higher cost to obtain land, which leads to higher urban land prices. Table 2 shows that the estimate of l_{ag} is positive and statistically significant at the 1% level. This confirms the theoretical arguments. As for the variable t_l, Table 2 indicates that its estimate is positive and significant at the 1% level, which is consistent with the theoretical expectation that a higher rate of property tax on land would increase the cost to obtain land, which could raise the urban land prices. This also implies that the imposition of effective property tax on land plays a significant role in the control of the demand for urban land. Finally, the interest rate is involved in both supply and demand sides of land, so it is difficult to predict theoretically the sign of its estimate. Table 2 shows 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.

4.3 Diagnostic Tests

In obtaining the above estimated results by 2SLS and 3SLS, all the exogenous variables in the system are used as the instruments. How valid are these instruments? Now, we apply the Sargan test (Sargan, 1964) to check. The null hypothesis of the Sargan test is that all instruments used are valid. If the computed chi-square exceeds the critical 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 3.549 and 3.432, respectively. Both are less than 3.841, which is the 5% critical value in the chi-square distribution with one degree of freedom, 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 simultaneous equations system again by GMM, because it can address the heteroskedasticity problem, which could occur in the panel-data used in this paper. We use the GMM described by Wooldridge (2002) to re-estimate the simultaneous equations system. Table 3 presents the estimated results by 2SLS, 3SLS, and GMM.

As shown in Table 3, the results of using 2SLS, 3SLS and GMM are similar. The estimate of the property tax rate on housing (t_h) by GMM is less significant than that by 2SLS and 3SLS, whereas the estimate of the excepted growth rate of housing prices (e) by GMM is more significant. However, other coefficients and their standard errors by GMM are very similar to those for 2SLS and 3SLS in both land prices and housing prices functions. Therefore, we can conclude that the original estimation results are robust when

Table 3. Tests on the robustness of estimation

Variables	2SLS	3SLS	GMM
For housing prices equation			
Average prices of residential land (p_l)	0.443*** (0.084)	0.433*** (0.082)	0.435*** (0.093)
Construction prices (p_s)	1.073*** (0.177)	1.095*** (0.175)	1.186*** (0.213)
Interest rate (i)	0.254*** (0.041)	0.258*** (0.040)	0.244*** (0.045)
Prefectural per capita income (Y)	0.234** (0.118)	0.274*** (0.115)	0.384*** (0.101)
Prefectural population (N)	0.0007*** (0.0002)	0.0007*** (0.0002)	0.0006*** (0.0002)
Ratio of per unit property tax on housing to per unit price of new-built condominiums (t_h)	−1.002*** (0.340)	−0.888*** (0.330)	−0.952* (0.506)
Average rate of adjusted regional consumer prices index (e)	0.062* (0.036)	0.059* (0.035)	0.065** (0.030)
R-squared/J-statistic	0.924(1)	0.923(1)	0.092(2)
For land prices equation			
Average sale prices of new-built condominiums (p_h)	0.594*** (0.089)	0.588*** (0.087)	0.513*** (0.083)
Construction prices (p_s)	−0.490*** (0.169)	−0.487*** (0.167)	−0.382*** (0.154)
Interest rate (i)	−0.030 (0.029)	−0.030 (0.028)	0.018 (0.025)
Prices of paddy fields and fields converted to residential land (p_{ag})	0.067*** (0.008)	0.067*** (0.008)	0.077*** (0.008)
Ratio of per unit property tax on residential land to per unit price of residential land (t_l)	0.482*** (0.190)	0.450*** (0.184)	0.386** (0.165)
R-squared/J-statistic	0.950(1)	0.950(1)	0.092(2)
Observations	200	200	200

Note: (1) The figure is R-squared; (2) the figure is J-statistic.

different estimation methods are used.

4.4 Implications of the Estimated Results

The above estimated results indicate several interesting implications. 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 two-way influence between land prices and housing prices in Japan. This result is similar to Potepan (1996), who pointed out that an endogenous interplay exists between housing prices and land prices in the US housing market.

Second, for the interest rate appearing in both price functions, our estimated results show that it has a positive influence on housing prices, whereas it has no effect on land prices. This is different from previous studies, which concluded that the interest rate played an important role in land prices before the bubble in the 1980s. The reasons are that, firstly, the previous work used a single-equation method (Nakamura et al., 2007) and did not take into consideration the issue of endogeneity between housing prices and land prices. Secondly, the dataset in this paper concerns the period 1990 to 2009, which does not involve the bubble period in the 1980s.

Finally, with the respect to the effect of property tax on housing and land, the estimated results indicate that the property tax rate on housing has a negative effect on housing prices, whereas the property tax rate on land has a positive impact on land prices. This finding is similar to Yamazaki et al. (2008), who pointed out that a higher housing property tax rate increases the user cost and reduce housing demand, which decreases housing prices. Meanwhile, a higher property tax rate on land could control the demand to develop urban land.

5 Conclusions

This paper empirically studied the determination of urban land and housing prices in Japan, using modern urban economics as the theoretical basis and a dataset of 10 prefectures in Japan over the period from 1990 to 2009 for empirical estimation. It used 2SLS and 3SLS to address the issue of endogeneity in land and housing prices and obtained significant estimated results. The estimated results show that land prices and housing prices affect each other, which indicates a bidirectional influence between land prices and housing prices in Japan's major prefectures. It was also found that housing prices depend not only on fundamental factors, such as the size of population, per capita income, and construction prices, but also on the user cost, which consists of the property tax rate, the expected growth rate of housing prices, and the interest rate. This implies that the implement of property tax on housing will help control housing prices in Japan. Meanwhile, agricultural land prices, construction prices, and the rate of property tax on land have significant effects on land prices. This suggests that an effective tax system of property tax on land could influence the development of land and would be useful to restrain excessive demand for residential land. This paper presented an attempt to explore the determination of Japanese land and housing prices using a simultaneous equations approach. We believe that it will contribute to a more complete understanding of the current Japanese real estate market.

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