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Leung, Charles Ka Yui; Chow, Kenneth; Yiu, Matthew and Tam, Dickson
City University of Hong Kong, Hong Kong Institute of Monetary Research, Hong Kong Monetary Authority

2010

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Charles Ka Yui Leung

City University of Hong Kong[Ω]

Kenneth K. Chow

Hong Kong Institute for Monetary Research

Matthew S. Yiu

Hong Kong Institute for Monetary Research

Hong Kong Monetary Authority

Dickson C. Tam

China International Capital Corporation Limited

December 2010

[♣] Acknowledgement: We are very grateful to the comments and suggestions by the referees and seminar participants of AsRES meeting and the HKMA. Leung is grateful to the financial support from the City University of Hong Kong, Chow and Yiu are grateful to the support from HKMA and HKIMR. The views expressed in this paper are solely those of the authors and do not necessarily reflect those of the CICC, HKIMR, HKMA, its Council of Advisors or Board of Directors.

[Ω] Correspondence: Leung, Department of Economics and Finance, City University of Hong Kong, Kowloon Tong, Hong Kong. (email) kycleung@cityu.edu.hk.

Abstract

This paper attempts to contribute in several ways. Theoretically, it proposes simple models of house price dynamics and construction dynamics, all based on forward-looking agents' maximization problems, which may carry independent interests. Simplified version of the model implications are estimated with the data from four major cities in China. Both price and construction dynamics exhibit strong persistence in al cities. Significant heterogeneity across cities is found. Our models out-perform widely used alternatives in in-sample-fitting for all cities, although similar success only limited to highly developed cities in out-of-sample forecasting. Policy implications and future research directions are also discussed.

Keywords: pre-sale, production constraint, collateral constraint, cross-city heterogeneity, fundamental versus policy

JEL Classification: C33, E30, R00

1. Introduction

The China property market has experienced an unprecedented growth in the last few years.[1] From 1998 to 2007, the property price index increased by more than 50%. Moreover, it has been related to the aggregate economy in many important dimensions, in the manner *similar* to many developed economies. An obvious example is the consumer price inflation. According to Peng, Tam and Yiu (2008), the property price was the second largest contributor to the upsurge in China inflation in the period from 2002 to 2004. And, as in the United States and many OECD countries, the property market also contributes significantly to public finance.[2] After the abolition of the administrative housing allocation system in 1998 and the implementation of the auction policy for land, the revenue from land sales became an important source of income to both the local and central governments in China.[3] The property market also appears in the discussion of the development and stability of the banking sector, as in the case of other countries.[4] For instance, Deng and Fei (2008) find that the ratio of mortgage loan balances to total bank loans increased from 0.5%

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[1] The rapid urbanization and high GDP growth have been pushing forces of this real estate market boom in China recently. The expansion of the mortgage business, which provides sufficient liquidity to the market, might also have played a significant role in boosting the property market. Moreover, the People's Republic of China implemented a policy in 1998 to encourage the commercial banks to expand the mortgage business and provide financial support to housing consumption after the elimination of the welfare house distribution policy, which is entitled "Management Provisions on Residents Housing Loan" according to Leung and Wang (2007). Over 60% of the real estate investment is financed by bank loans (Liu and Huang, 2004). Peng, Tam and Yiu (2008) also find that the growth of rental price, land price, inflation and GDP are exerting a positive impact on the real estate market.

The focus of this paper, however, is not on the growth of the property market itself, but rather how well a market-based economics model can explain the property market in China.

[2] Clearly, it is beyond the scope of this paper to review the literature on this topic. Among others, see Hanushek (2002, 2006), Ross and Yinger (1999) and the references therein.

[3] This revenue is even more important for the local government since 40% of the revenue goes to the central government while the local government takes the rest (Chan, 1999). For the case of the United States, see Hanushek and Yilmaz (2007a, b), among others.

[4] Again, it is beyond the scope of this paper to review the literature on this topic. Among others, see Chen (2001), Chen and Wang (2007, 2008), Mera and Renaud (2000), and the references therein.

in 1998 to more than 10% in 2004. The housing wealth also constitutes a large share and plays a very important role in the household portfolio in China, as many recent works have recognized in other developed countries.[5] For instance, Liu and Huang (2004) report that home equity took about 47.9% of the Chinese household wealth in 2002 according to an urban survey of National Bureau of Statistics of China. In 2003, the central government announced the real estate sector as one of the pillar industries of the Chinese economy, which seems to be an unprecedented official statement both in the economic history of China and among socialist countries. All these demonstrate two facts. Apparently the importance of the property market in the Chinese Economy is growing. In addition, the role of the property market in the aggregate economy in China has become *increasingly similar* to the case of other developed countries.

Thus, to complement the voluminous empirical literature on the China real estate market,[6] this paper attempts to contribute in several ways.

1. Most of the literature is purely empirical. For those containing theoretical models, they are either static or at most two periods. In contrast, this paper provides two infinite-horizon models in which agents are forward-looking and the first order conditions that we derive naturally tied the choice variables (such as how much housing to consume) to the market variables (such as the prices and interest rate).
2. Most of the literature is in reduced form regression. In this paper, we first derive first-order-conditions (FOC) from agents' dynamic optimization problems. We then estimate a linearized version of those first order conditions. This is in line with the "structural estimation" literature promoted by Hansen (1982), Hansen and Sinleton (1982), and recently, Piazzesi, Schneider and Tuzel (2007). (Singleton (2006) provides a textbook treatment on such an approach.) This approach provides us a "micro-foundation" for the empirical work and a more explicit linkage between the theory and the empirics.

[5] Once again, this literature is too large to be reviewed here. Among others, see Cocco (2004), Yao and Zhang (2005), Piazzesi, Schneider and Tuzel (2007).
[6] It is clearly beyond the scope of this paper to review this literature. Among others, see Peng, Tam and Yiu (2008), Deng, Zheng and Ling (2005), and the references therein.

3. The dynamic models we provide, including the one in the appendix, are general in nature, and could be modified for other applications. Thus, it may carry some independent interests.
4. This paper performs out-of-sample-forecasting (OSF) and finds that the simple models proposed here match the data reasonably well. To our knowledge, most empirical works on China do not perform OSF. (The importance of OSF have been discussed by Meese and Rogoff, 1983; Cheung, Chinn and Pascual, 2005, among others).
5. Perhaps even more importantly, this research strategy will test empirically whether real estate economics models developed in the tradition of the main stream economics are capable to account for the dynamics of the China property market. Given the fact that the Chinese real estate market is constantly exposed to frequent and discretionary government intervention,[7] and the well known micro-level differences,[8] it is not clear why models that are developed to explain the advanced economies will also be applicable in the Chinese economy, unless the market in China has indeed reached a certain level of maturity. To put it in another way, the economic reforms in China are now "significant enough to be detected" in the real estate market.

The house price and construction dynamics are chosen to be the focus of this study for obvious reasons. First, the China housing price and construction data series in China are more complete than other related series. Second, they are also more "visible" for the general public and the media, and therefore often are chosen as policy targets of the government. Limited by the data availability, we focus on the data series from four major cities, we can afford to estimate them separately and be able to present the results clearly. In particular, we would compare whether during a fixed sampling period, the same set of variables would have similar impact on the price and construction dynamics across different cities. In addition, we will conduct out-of-sample forecasting and compare the performance of our models with some

[7] See Leung and Wang (2007), Deng and Fei (2008), and the references therein, for more details.
[8] For instance, public facilities are funded locally in the United States but regionally in China. Among others, Hanushek and Yilmaz (2005, 2007) argue that this will have important implications for economic efficiency and social welfare.

widely used alternatives. To our knowledge, thus far there has been no attempt to conduct empirical test which are directly derived from maximization modes, and to conduct both in-sample-fitting and out-of-sample forecasting for China housing market at the city level. This paper takes an initial step towards this direction.

The reasons to focus only on the quarterly data from four major Chinese cities, namely, Beijing, Tianjin, Shanghai and Chongqing, from 1998 to 2008 are clear. Their data series are relatively longer (which will enhance the study of market dynamics) and they are also relatively more developed in China. Their housing markets are expected to be more market-driven so that the model should be more applicable to these cities. Our approach reflects our assumption that housing markets in cities at different stages of economic development and different industrial specialization may behave differently. To complement the previous literature, which are either based on cross-sectional regressions, or the panel data approach with city-fixed effects, this paper would rather study these cities separately, and thus allowing the quantitative relationships among variables are indeed very different across cities. In fact, our results seem to justify our "priors" and we will explain the results in details in the following section.

The organization of this paper is as follows. Section 2 describes the methodology. The details of the regression equations we use, different estimation approaches and the estimation issues will be discussed in this section. Section 3 presents the empirical results and discussions. The final section will discuss the policy implications and conclusions.

2. Methodology

In this paper, we intend to build two simple dynamic models, one for the housing price and one for the construction. And based on the theoretical results from those models, we will propose two simple empirical models, which will in turn be estimated with the China data. We will assess the performance of those empirical models based on both in-sample fitting and out-of-sample forecasting. In this section, we will first present the theoretical model of house price, followed by the empirical counterpart. We then switch to a simple model of construction, which will also be followed by its empirical counterpart.

2.1 A simple Model of House Price

This section proposes a simple model of city level house price, which would provide some guidance for our empirical investigation. Following the consumption-based house price model of Kan et al (2004), Leung (2003, 2007), we assume that there is a forward-looking, representative consumer in a city, which maximize the lifetime utility $\max \sum_{t=0}^{\infty} \beta^t U\left(C_t, H_t\right)$, subject to the budget constraint in each period, with $\beta \in \left(0,1\right)$ is the discount factor. For simplicity and following Greenwood and Hercowitz (1991), we assume that the utility function is separable in the non-durable consumption C_t and the housing stock H_t,

$$U\left(C_t, H_t\right) = \ln C_t + \omega \ln H_t,$$

where $\omega > 0$ is the parameter governs the relative importance of non-durable consumption C_t and the housing stock H_t in the utility function. To ensure "time-consistency," we adopt the dynamic programming approach in solving the model. The Bellman equation for the dynamic optimization can be written as

$$V\left(H_t; W_t, P_t, P_{t-1}, R_t\right) = \max U\left(C_t, H_t\right) + \beta V\left(H_{t+1}; W_{t+1}, P_{t+1}, P_t, R_{t+1}\right)$$

subject to the budget constraint,

$$W_t + P_t H_t^s \geq C_t + \gamma P_t H_{t+1}^s + (1-\gamma) R_t P_{t-1} H_t^s + R_t^h H_t^r , \qquad (1)$$

where W_t is the wage, P_t is the per unit house price, H_t^s is the stock of housing purchased in the previous period and owned in the current period, γ is the down-payment ratio, R_t is the interest factor imposed on the mortgage carried from period (t-1) to period t, R_t^h is the rent for rental housing, H_t^r is the amount of rental housing for the current period. For simplicity, we simply assume that the consumer treats the owner-occupied housing H_t^s and rental housing H_t^r as perfect substitute.

$$H_t = H_t^s + H_t^r$$

This formulation of budget constraint follows both Kan et al (2004) and Chen, Chen and Chou (2010). It simply formulates the idea that the total revenue (the left hand side of (1)), which is the sum of the wage and the re-sale value of the house, should exceed the total expenditure (the right hand side of (1)), which is the sum of the total value of consumption, the down-payment for the house purchase in the current period, and the mortgage debt carried from the last period.

Following the method in Kan et al (2004), the first order conditions are easy to derive,

$$\lambda_t = 1 / C_t ,$$

$$\frac{1}{\lambda_t} = \frac{R_t^h \left(H_t^s + H_t^r \right)}{\omega} ,$$

$$\lambda_t \gamma P_t = \beta \left\{ \omega \left(H_{t+1}^s \right)^{-1} + \lambda_{t+1} \left[P_{t+1} - (1-\gamma) R_{t+1} P_t \right] \right\} .$$

Combining these equations and after some algebraic manipulations, we have

$$\frac{P_{t+1}}{P_t} = \left(\frac{\gamma}{\beta}\right)\left(\frac{C_{t+1}}{C_t}\right) - \omega\left(\frac{C_{t+1}}{P_t H^s_{t+1}}\right) + (1-\gamma) R_{t+1},$$

$$C_t = \frac{R^h_t \left(H^s_t + H^r_t\right)}{\omega}.$$

Or, the two expressions can be combined as

$$\frac{P_{t+1}}{P_t} = \left(\frac{\gamma}{\beta}\right)\left(\frac{R^h_{t+1}}{R^h_t}\right)\left(\frac{H^s_{t+1} + H^r_{t+1}}{H^s_t + H^r_t}\right) - \omega\left(\frac{C_{t+1}}{P_t H^s_{t+1}}\right) + (1-\gamma) R_{t+1}. \quad (1')$$

Notice that most variables in (1') are available and hence in principle, we can directly estimate (1') with GMM or other nonlinear econometric technique. However, with only 40 quarterly data points, it is difficult, if not impossible, to do so. Following the log-linear approximation method of King, Plosser and Rebelo (2002), the equation above can be roughly approximated as

$$GP_{t+1} = a_0 + a_1 GR^h_{t+1} + a_2 GH_{t+1} - a_3\left(\frac{C_{t+1}}{P_t H^s_{t+1}}\right) + a_4 R_{t+1}. \quad (2)$$

Thus, this simple model suggests that the growth rate of house price GP_{t+1} is related to the growth rate of the house rent GR^h_{t+1}, the growth rate of the housing stock GH_{t+1}, a change of the ratio between the expenditure on non-durable consumption versus the value of the housing wealth $\left(C_{t+1} / P_t H^s_{t+1} \right)$, and the mortgage interest rate R_{t+1}. Clearly some of the variables such as GP_{t+1} and GR^h_{t+1}, are much more accessible to the authors than the others. In the next section, we will discuss in more details how the empirical work is implemented.

2.2 An empirical House Price Model

This section attempts to study the housing market dynamics of some major cities in China. Our estimation is "linear in form" and "structural" by nature. Inspired by the simple theoretical analysis of the previous section, we envision that the housing price follows the following process,

$$GP_t = \varphi[\gamma_1 GR_t + \gamma_2 GWAGE_t + \gamma_4 DU_t] + (1-\varphi)GP_{t-1} \qquad (3)$$

where G*P* is the growth rate of the overall property price index, *GR* is the annual growth rate of the real rental, *GWAGE* is the growth rate of household real disposal income, *DU* is the annual difference of the real lending rate for housing loans as a measure of user cost of homeownership. Roughly speaking, equation (3) is broadly consistent with growth models with endogenous real estate price (among others, see Tse and Leung, 2002; Leung, 2003).

The intuition behind this equation is very simple. First, the theoretical result in the previous section suggests that the growth rate of property price is (intuitively) related to the growth of the housing rental rate. There are additional reasons why we would focus on the growth rate of the house price instead of the levels. During our sampling period, the house price of China has a clear upward trend. Estimating these potentially non-stationary data series directly may lead to spurious regressions. A suitable de-trending[9] of the level data is therefore appropriate. Moreover, the level data of the China property price is not available in quarterly frequency. *Only the growth rate of the property price at city level is accessible*. Thus, focusing on the growth rate of property price is well-justified in all kinds of consideration. This also helps us to differentiate from some of the earlier efforts which tend to focus on the cross-sectional difference of the house prices across cities.

9 There is a tradition in macroeconomics which is to de-trend the original non-stationary time series and focus on the de-trended quantities and prices, and the "growth rate" of a variable can be interpreted as the first-difference-filtered variable. See Baxter (1991), King et al. (2002), King and Rebelo (1993), among others, for more discussion.

The other terms in equation (2) are difficult to find accurate quarterly measures for all cities. Thus, we need to use proxies. First, on a quarterly basis, the total stock of housing may not change as much as the other variables and we might therefore switch the attention to the other variables, such as the change of the ratio between the expenditure on non-durable consumption versus the value of the housing wealth $\left(C_{t+1} / P_t H_{t+1}^s \right)$. In case of separable utility function, as we assume here, this term is likely to be stationary over time. However, the utility function of a representative agent may not be separable in non-durable consumption and housing in practice. In fact, some empirical works suggest that the utility function is indeed non-separable.[10] In the appendix, we solve for the non-separable case and find that it is even more difficult to find an appropriate proxy in practice. On the other hand, as shown by the work of Atkeson and Ogaki (1996), Ogaki and Atkeson (1997), the change in the relative importance of non-durable consumption (such as food) versus housing is related to the income. Since wage is a non-stationary variable during the sampling period, we use the growth rate of wage instead.

Another term that appears in equation (2) is the interest rate. As mentioned by Liu and Huang (2004), over 60% of the real estate investments are financed by bank loans in China. Thus, the interest rate can be an important factor. Since the interest rate is non-stationary, we use the annual difference of the real lending rate for housing loans (*DU*) will serve as a measure of user cost of homeownership in the regression.

The last term reflects that the growth rate of housing price may have some persistence (and thus GP_t may depend on GP_{t-1}). This can be due to the informational friction. In contrast to the United States, the information flow is slower

[10] Among others, see Atkeson and Ogaki (1996), Ogaki and Atkeson (1997).

and the market transparency is lower.[11] It may also be due to behavioral reason such as momentum, or because of the persistence of technological shocks, or because of habit formation in the preference.[12] Moreover, all of the estimations will be based on *quarterly* data. Thus, serial correlation of prices that may not appear in some previous literature (which employ only annual data) may nevertheless be found in quarterly data.[13]

Clearly, some other variables may also be important, such as the housing stock data, the construction data, the evolution of the demography of each city, the age-dependent home ownership rate, etc. Unfortunately, those variables are not available for the whole sampling period. By the same token, we are unable to identify quarterly price data for each type of real estate in each city. Only the overall property price index can be obtained. Fortunately, in these major cities, the residential property constitutes more than 60% weight in the overall price index. Moreover, as these cities are rapidly growing and resources are being intensively competed. As a result, the prices of different types of property tend to move together. Equation (3) thus represents a compromise of the "ideal model" we would like to estimate and the data available for estimation. As it will become clear, despite all these limitations, our simple model achieves moderate success, as it will be clear in later sections.

The expected signs are the other coefficients are straightforward. With regard to the rental growth (*GR*), a positive coefficient is expected because housing can also be regarded as an investment asset. If the rental growth increases, the return on holding real estate assets becomes higher, which will attract more capital to go into the real

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[11] For instance, during most of our sampling period, second hand market transaction data are not available from the government, but only through real estate agents, who have strong incentive to selectively report or even mis-report.

[12] Among others, see Leung (2007), Leung and Chen (2006) for a discussion and explicit modeling of the equilibrium dynamics of real estate price.

[13] It is a well-known fact in time series that data with higher frequency may exhibit more correlations with lag than the lower frequency counterparts. Among others, see Hamilton (1994) for more details.

estate market and lead to higher housing prices. Similarly, the household disposal income growth (*GWAGE*) is expected to have a positive effect on price as faster household income growth will normally generate a greater demand for housing.

A higher growth rate of the interest factor, however, can have different impacts. On the one hand, if the interest factor grows fast, it will increase the opportunity of house purchase, and would suppress the growth rate of the house price. On the other hand, the interest factor is indeed an endogenous variable. The increase in the interest factor may simply reflect a strong demand in housing (and other assets) and the central bank in China needs to "intervene" by increasing the opportunity cost of house ownership. Thus, the net effect of the interest rate change on the house price growth can go either way, leading to ambiguous prediction on the coefficient in the linear regression.

2.3 A Simple Model of Construction

The theoretical literature on construction and real estate development is voluminous and it is clearly beyond the scope of this paper to review it here. Wang and Zhou (2006), among others, provide an excellent review of the literature. More recently, the literature also embeds the pre-sale behavior of the developers into the model, such as Lai, Wang and Zhou (2002), Chan, Fang and Yang (2008), Liu, Edelstein and Wu (2009), among others. While the simple theoretical model builds on their insights, it has a very different focus, which is to relate the construction activities (developer side) to the land price and house price in a dynamic setting. To maintain the tractability of the model, some simplifying assumptions are made. They can be justified by the work mentioned above. To explicitly model those choices, however, will make the model *un*-necessarily complicated and distract the readers from seeing the main results.

Following the work of Kan et al (2004), this section considers a representative developers who takes the prices as given and maximizes an infinite flow of profit, $\sum_{t=0}^{\infty}\beta^{t}\pi_{t}$, where π_{t} is the profit at time t, which can be expressed in the following way,

$$\pi_t = \alpha P_t^h H_t + (1-\alpha) P_t^h H_{t+1} - I_t^c - \xi P_t^l L_t - (1-\xi) P_{t-1}^l L_{t-1} R_t \qquad (4)$$

The idea behind this expression is simple. We assume that the developer sells a fraction α, $0<\alpha<1$, of the housing units he produced at period t at the market price P_t^h, i.e. H_t, and pre-sell a fraction $(1-\alpha)$ of the housing units he will complete at period (t+1), i.e. H_{t+1}, also at the market price P_t^h. Thus, we ignore the potential "pre-sale discounting" or pricing-in issues, for simplicity. These are the revenue of the developer. He has three sources of expenditure. On top of the investment expenditure I_t^c, the developer needs to pay for the land, which is necessary for the construction.[14] We assume that the developer receives some kind of short term loan ("bridging loan") so that he only needs to pay for a fraction ξ, $0<\xi<1$, of the value of land purchased at time t, $P_t^l L_t$, where L_t is the amount of land the developer purchases at the market price of land at time t, P_t^l. In addition, the developer needs to pay for the residual amount of the value of land purchased in the previous period (interest included). Since the developer has already paid for the fraction ξ of it in the previous period, he only needs to pay the remaining fraction $(1-\xi)$ of it. This is the last term $(1-\xi)P_{t-1}^l L_{t-1} R_t$, where R_t is the interest factor imposed on the loan between period *t* and period (*t+1*).

[14] Notice that we have used "C" to represent non-durable consumption in the previous section, and therefore we will use "I^c" to represent the investment in construction in here.

The developer faces two constraints. The production constraint dictates the amount of housing that can be produced given the investment and inputs,

$$H_{t+1} \leq \left(I_t^c\right)^{\eta_1} \left(L_{t-1}\right)^{\eta_2}, \tag{5}$$

where $0 < \eta_1, \eta_2 < 1$ are parameters governing the marginal product of each input in the production function. Notice also that land needs to be purchased in period (*t-1*) while investment is made in period *t* for the housing to be delivered in period (*t+1*). This differential in timing captures the observation that some preparation works need to be done first (including the management of underground water, etc.) before real construction works are possible.

The second constraint concerns the collateral constraint of the developer. Previous theoretical work such as Hart and Moore (1994), Chen (2001), and empirical work such as Chen and Wang (2007, 2008), Wang and Chang (2008), among others, all suggest that the collateral constraint is important for firms. Empirical finance researches also suggest that the capital structure may be important in the investment decisions of firms.[15] In the current context, we assume that the value of debt due to land purchase does not exceed the value of houses that will be completed in the next period and have not been pre-sold. Formally, it means that

$$\alpha P_{t+1}^h H_{t+1} \geq \left(1-\xi\right) P_t^l L_t R_{t+1}. \tag{6}$$

As in Kan et al (2004), we adopt the dynamic programming approach to ensure "time consistency" of this maximization problem. The Bellman equation can be written as

$$\Psi\left(L_{t-1}, H_t\right) = \max \pi_t + \beta \Psi\left(L_t, H_{t+1}\right)$$

[15] Among others, see Myers (2003) for a review of the literature.

subject to the constraints (5) and (6), where π_t is given by (4). The first order conditions are easy to derive with the Kuhn-Tucker Theorem,[16]

$$1 = \lambda_{1t}^{c}\eta_1\left(I_t^c\right)^{\eta_1-1}\left(L_{t-1}\right)^{\eta_2}$$

$$\xi P_t^l + \left(1-\xi\right)\lambda_{2t}^{c}P_t^l R_{t+1} = \beta\left(\frac{\partial\Psi(.)_{t+1}}{\partial L_t}\right)$$

$$\beta\frac{\partial\Psi\left(.\right)_{t+1}}{\partial H_{t+1}} = \lambda_{1,t}^{c} - \lambda_{2,t}^{c}\alpha P_{t+1}^{h} - \left(1-\alpha\right)P_t^h$$

where λ_{1t}^{c}, λ_{2t}^{c} are the Lagrangian multipliers of (5) and (6) respectively, $\Psi\left(.\right)_{t+1}$ is the shorthand for the value function at time period (*t+1*), $\Psi\left(L_t, H_{t+1}\right)$. By envelope theorem, we have

$$\frac{\partial\Psi\left(.\right)_{t+1}}{\partial L_t} = -\left(1-\xi\right)P_t^l R_{t+1} + \lambda_{1,t+1}^{c}\eta_2\left(I_{t+1}^c\right)^{\eta_1}\left(L_t\right)^{\eta_2-1},$$

$$\frac{\partial\Psi\left(.\right)_{t+1}}{\partial H_{t+1}} = \alpha P_{t+1}^h.$$

At the equilibrium, the production constraint, i.e. equation (5), must be binding, otherwise the profit is not maximized. The collateral constraint, i.e. equation (6), may not be binding. Therefore we need to study the two cases separately.

Case (a): Collateral constraint is not binding.

In other words, $\alpha P_{t+1}^h H_{t+1} > \left(1-\xi\right)P_t^l L_t R_{t+1}$ and $\lambda_{2t}^{c} = 0$. The dynamical system can then be reduced to

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[16] Among others, see Sundaram, R. (1996) for more details.

$$I_t^c = \lambda_{1t}^c \eta_1 H_{t+1},$$

$$\xi P_t^l + (1-\xi)\beta P_t^l R_{t+1} = \beta \eta_2 \lambda_{1,t+1}^c (H_{t+2} / L_t),$$

$$(1-\alpha) P_t^h + \alpha(\beta P_{t+1}^h) = \lambda_{1t}^c \quad .$$

They imply that

$$\frac{I_{t+2}^c}{I_{t+1}^c} = \left(\frac{P_{t+1}^l}{P_t^l}\right)\left(\frac{L_{t+1}}{L_t}\right)\left(\frac{\xi + (1-\xi)\beta R_{t+2}}{\xi + (1-\xi)\beta R_{t+1}}\right)$$
$$= \left(\frac{(1-\alpha) P_{t+1}^h + \alpha\beta P_{t+2}^h}{(1-\alpha) P_t^h + \alpha\beta P_{t+1}^h}\right)\left(\frac{H_{t+2}}{H_{t+1}}\right) \tag{7}$$

which suggests that the growth rate of construction investment will depend on the growth rate of land price, P_{t+1}^l / P_t^l, the growth rate of land purchase, L_{t+1} / L_t, and some adjusted ratio of the interest factor, $(\xi + (1-\xi)\beta R_{t+2}) / (\xi + (1-\xi)\beta R_{t+1})$. Alternatively, it can also be expressed as the ratio of weighted average of house prices in different periods, $((1-\alpha) P_{t+1}^h + \alpha(\beta P_{t+2}^h)) / ((1-\alpha) P_t^h + \alpha(\beta P_{t+1}^h))$. There is, however, another case that we should also consider.

Case (b): Collateral constraint is binding.

In other words, $\alpha P_{t+1}^h H_{t+1} = (1-\xi) P_t^l L_t R_{t+1}$ and $\lambda_{2t}^c > 0$. The dynamical system will then become

$$I_t^c = \lambda_{1t}^c \eta_1 H_{t+1},$$

$$\lambda_{2,t}^c = -\beta + \left(\frac{1}{\alpha \eta_1}\right)\left(\frac{I_t^c}{P_{t+1}^h H_{t+1}}\right) - \left(\frac{1-\alpha}{\alpha}\right)\frac{P_t^h}{P_{t+1}^h},$$

$$P_t^l\left[\xi+(1-\xi)R_{t+1}\left(\lambda_{2,t}^c+\beta\right)\right]=\left(\frac{\eta_2\beta}{\eta_1}\right)\frac{I_{t+1}^c}{L_t}.$$

The last two expressions together imply that

$$\begin{aligned}\left(\frac{\eta_2\beta}{\eta_1}\right)\left(\frac{I_{t+1}^c}{I_t^c}\right)&=\left(\frac{P_t^l L_t R_{t+1}}{P_{t+1}^h H_{t+1}}\right)\left(\frac{1-\xi}{\alpha\eta_1}\right)\\&+\left(\frac{P_t^l L_t}{I_t^c}\right)\left[\xi+(1-\xi)\left(\frac{1-\alpha}{\alpha}\right)R_{t+1}\left(\frac{P_t^h}{P_{t+1}^h}\right)\right]\\&=\left(\frac{1}{\eta_1}\right)+\left(\frac{P_t^l L_t}{I_t^c}\right)\left[\xi+(1-\xi)\left(\frac{1-\alpha}{\alpha}\right)R_{t+1}\left(\frac{P_t^h}{P_{t+1}^h}\right)\right]\end{aligned}.$$

(8)

The last equality is due to the fact that $\alpha P_{t+1}^h H_{t+1}=(1-\xi)P_t^l L_t R_{t+1}$. This expression (8) suggests that the growth rate of construction investment will depend (in a nonlinear manner) on the growth rate of the house price, P_{t+1}^h/P_t^h, the current level of residential investment, the value of land holding $P_t^l L_t$, the interest factor, etc.

2.4 An Empirical Construction Equation

The previous theoretical analysis suggests that the growth rate of the construction could depend on several factors and whether the real estate developers are being constrained or not. In a complete market, there is a one-to-one corresponding between the "price side" and the "quantity side" by the duality theory.[17] In that case, it suffices to study the price dynamics and we can safely ignore the construction dynamics. Unfortunately, markets are far from being complete in practice, especially for the China real estate market. Therefore, it is necessary to

[17] Among others, see Mas-Colell, Whinston and Green (1995) for more details.

estimate another equation on the "quantity side" separately. Since our sampling period is rather short (with less than 40 observations), we restrict our attention to the case of a linear model.[18] Inspired by the theoretical analysis in the above section, we consider the following equation for estimation.

$$GC_t = \delta_1 + \delta_2 GP_t + \delta_3 DTREAL_t + \delta_4 GLPI_t + \delta_5 GC_{t-1}, \qquad (9)$$

where *GC* is the growth rate of residential commodity building construction started, *GP* is the growth rate of the real housing price, *DTREAL* is the annual difference of the real lending rate. *GLPI* is the growth rate of the real land price. Clearly, the corresponding coefficient δ_5 measures the persistence of the growth of new construction.

The rationale of this equation is straightforward. The theoretical analysis in the previous section shows that the growth rate of the construction started GC_t could depend on the growth rate of the house price, the change in the interest factor, the growth rate of the land price. Therefore, we include those variables in the equation (9). Obviously, a higher growth rate of the house price will encourage more construction work to start. A higher growth rate of the interest factor, however, can have different impacts. On the one hand, if the interest factor grows fast, it will discourage developers from building new houses. On the other hand, the interest factor is somewhat endogenous. The central bank in China, just like central banks in other countries, tends to increase the interest rate when the economy is "hot." In other words, there is likely to be a high demand for housing and the central bank attempts to "stabilize" the market by increasing the interest rate. In other words, an increase in the interest rate simply represents an underlying strong demand for housing. Thus, the net

[18] If we apply GMM directly on equation (7) and (9), severe bias is likely to be the result. Among others, see Christiano and Den Haan, 1996. To apply the threshold regression model, we will need much longer time series. For instance, see Chen, Chen and Chou (2010).

effect of the interest rate change on the construction growth can go either way, leading to ambiguous prediction on the coefficient in the linear regression.

The same intuition applies to the growth rate of the land price. Other things being equal, an increase in the growth rate of land price will increase the construction cost and hence discourage the construction work to increase. However, other things are typically not equal. The land price increases because it reflects a strong economic growth being foreseen or a significant demand increase being perceived. Thus, the growth rate of construction started can also be positively associated with the growth rate of the land price.

There are reasons to suspect that housing construction may indeed be serially correlated. First, housing construction takes time and therefore a single project may take several periods to be finished, creating a serial correlation in the data. It is especially true in this quarterly frequency dataset. Also, if the productivity shock is persistent over time, developers would increase their construction in consecutive periods, as in Leung (2007).

Notice that the growth rate of price is included in the construction equation (9), but construction does not enter the pricing equation (3). The reason is very simple. Price can change instantly while construction may take time to adjust, perhaps due to some ongoing projects. Thus, even though both house price and new construction are both endogenous variables from a dynamic equilibrium point of view, the house *price can adjust much faster* and would capture information about future changes. In this sense, price is a “more forward-looking” variable than the construction level. Therefore, it makes sense to include price in the construction equation (9) in order to capture information that may not be available for the econometrican yet are known to the market participants. By the same token, we should not include the construction level in the price equation (3) as it may not capture much extra information about the future.

Again, there are other variables such as the land holding, the amount of housing stock on the market, etc. that could be included in the construction equation (9). Unfortunately, data of those variables are not available for the regression.

3. Data and Estimation Results

Our empirical procedures contain two parts. The first part is to study the housing price and housing construction dynamics in the four major cities in China, based on equations (3), (9). For the house price equation (3), we estimate the model with data from 2000Q3 to 2007Q4, the most accessible to the authors for all four cities (Beijing, Tianjin, Shanghai and Chongqing). For the construction equation (9), we estimate the model with data from 1998Q2 to 2007Q4. All data used in this paper are from the CEIC Data Ltd, a data provider whose data are from official sources. Table 1 and 2 provide some summary statistics. Constrained by the data, we simply apply OLS on each city separately.[19] As we have explained those linear regressions can be regarded as the linearization of the first order conditions resulted from the two dynamic models derived from above. Thus, the coefficients estimated from the regression carries "structural interpretations." We run the regressions separately for each city because cities could differ in terms of culture, economic development, legal, and other infrastructures, which would affect the estimated coefficients. This is our in-sample-fitting part. The second part is out-of-sample forecasting. We use our model to forecast the house prices and construction dynamics in 2008 in those four major cities in China.

[19] We have also tried the Panel data approach but given that we have only data from 4 cities, the panel data approach does not deliver much in extra. Further discussion on this will be followed.

(Table 1 and 2 about here)

In the literature, there are discussions on whether in-sample-fitting (ISF) or out-of-sample-forecasting (OSF) should be used as the criteria to measure the performance of an econometric model (among others, see Meese and Rogoff, 1983; Inoue and Kilian, 2004; Cheung, Chinn and Pascual, 2005). In this paper, we will consider both ISF and OSF. And to more accurately assess the performance of our model, we provide two widely used alternatives for comparison in both ISF and OSF.

We follow the literature to use both RMSE (Root Mean Squared Error) and MAE (Mean Absolute Error) as the metric for the models' ability to match with the data. We will first present the results regarding the house price equation, followed by those related to the construction equation.

Table 3 presents the regression results regarding the house price equation in individual cities. All models are *adjusted for heteroskedasticity and autocorrelation* by the Newey-West HAC Standard Errors and Covariance. Overall, the model works well in these four cities. In terms of the more conventional measure, the model applies pretty well in Beijing, achieving a R^2 of 0.90. The case for Tianjin and Shanghai are also reasonable good, with a R^2 of 0.80 or above. The case of Chongqing is a little below the norm, with a R^2 slightly below 0.60. It may be due to its relatively less developed economy, or due to a very different sectoral focus, and hence our model may not match that well. The diversity of the model performance also seems to justify our city-by-city approach.

(Table 3 about here)

For individual variable, the real growth rate of household income has a positive (and statistically significant) effect on the growth rate on house price change, as expected. The effect of rental growth is however insignificant. The effect of the user cost of homeownership is statistically significant only in Tianjin. The effect of the previous period growth rate of property price is always positively and statistically significant effect on the house price growth. Such persistence in house price is consistent with the equilibrium model where technological shocks are persistent and agents rationally respond to shocks (such as Leung, 2007).

We now turn to the in-sample-fitting. We compare our model with the two widely used alternatives, namely the 1st degree auto-regressive model (AR(1)) and the random walk. In terms of RMSE, our model out-performs the alternatives in all four cities, as shown in table 4a. In terms of MAE, our model still out-performs the alternatives in all except Chongqing, as shown in table 4b. Putting all these together, despite the simplicity, our model has apparently captured some important characteristics of the house price dynamics in these four cities during the sampling period (2000Q3 – 2007Q4).

(Table 4 about here)

In terms of the out-of-sample forecasting, our model does not do as well. In terms of RMSE, our model only out-performs the alternatives in Beijing, as shown in table 4c. In terms of MAE, our model out-performs the alternatives in both Beijing and Chongqing, as shown in table 4d. One possible explanation is that during the period of OSF (i.e. the period 2008Q1 -2008Q4), some changes occur in the market of Tianjin and Shanghai which are not captured by our model. We can only leave this to future research for more in-depth investigation.

We now turn to the construction equation (9). Table 5 reports the regression results. Overall, the results are even better than the counterpart of the house price equation. Despite its simplicity, the R^2 of Beijing is 0.95 and that of Shanghai is 0.93. Chongqing achieves a R^2 of 0.80. Tianjin achieves a R^2 of 0.73. This is consistent with the previous literature that dynamic models typically match the quantity dynamics better than the price dynamics.[20]

(Table 5 about here)

As we compare the effect of individual variable on the construction growth rate, we again notice the very significant diversity across cities, even though we are using the same econometric model. For instance, the growth rate of the property price has a positive and statistically significant impact on the construction growth in Tianjin. And the point estimate is 0.99. Thus, the effect from house price to construction is, in a sense, one-to-one! The counterparts in the other cities, however, are all statistically *insignificant*. In the case of the difference of lending rate, the coefficients are *negative* and statistically significant in Beijing and Shanghai, which are arguably more developed. The counterpart of Tianjin is *positive* and statistically significant. In Chongqing, the coefficient is also large in magnitude and is statistically significant at 10% level. This contrasting result between the relatively more developed cities and the relatively less developed is also observed in the case of the land price. While they are all statistically significant at 10% level, the coefficients of the growth rate of land price are positive in both Tianjin and Chongqing yet negative in Shanghai. Thus, the level of "market-ization" may affect how the housing started (or other real estate market variables as well) respond to the changes of the market conditions. And had we adopted the panel data approach which only uses a city-level fixed effect, we may not be able to capture such city-level heterogeneity.

Persistence, measured by the coefficient of the lagged construction growth rate on the current construction growth rate is always positive and statistically significant. Interestingly, the coefficients for both Beijing and Shanghai are above 0.90, while the counterparts for both Tianjin and Chongqing are between 0.70 and

[20] Among others, see Leung (2004) for a review of the literature.

0.80. Thus, even if the effect of a variable is positive in all cities, the magnitude of that effect can be different across cities.

In terms of the in-sample-fitting (ISF), our model again out-performs the alternatives in all cities according to RMSE, and in all cities except Chongqing according to MAE, as shown in table 6a and 6b. Just as the case of house price dynamics, our construction model seems to capture some important dynamics during the sampling period (1998Q2 -2007Q4).

(Table 6 about here)

Unfortunately, our out-of-sample forecasting (OSF) is not as successful as the ISF. In terms of RMSE, our model only out-performs the alternatives in Shanghai, as shown in table 6c. In terms of MAE, our model out-performs the alternatives in both Beijing and Shanghai, but not in Tianjin or Chongqing, as shown in table 6d. The results here are consistent with the previous conjecture that during the period of OSF (i.e. the period 2008Q1 -2008Q4), some changes occur which are not captured by our model. We again leave this to future research.

4. Concluding Remarks

Many have been written on the China housing market. This paper complements the existing literature by providing two simple dynamic models, in which households and developers are forward looking and respond to prices optimally. In particular, the household are bounded by the budget constraint and the developer pre-sells her housing units and is required to meet both the production constraint as well as the collateral constraint. These models deliver two nonlinear equations endogenously, one for price dynamics and one for construction dynamics. These equations relate the house price and construction to other variables, such as the land price, the interest rate, rental rate, etc. Since theoretical models are general and can be applied to different economies, we consider there may be an independent interest for these two models. In fact, an on-going research project is to further extend and develop them.

In the context of the major Chinese cities, with less than 40 observations in each series, we are unable to conduct structural estimation. Instead, we confront the linearized versions of them to the time series from four major cities in China (Beijing, Tianjin, Shanghai and Chongqing). We conduct the regression separately and hence allow the coefficients of the same variable taking different values across cities.

Several empirical results are obtained. Overall, our simple regression models perform reasonably well. Heterogeneity across cities, on the other hand, is very dramatic. For instance, in the case of house price equation, while Beijing achieves a R^2 of 0.91, Chongqing achieves 0.59. and while the growth rate of the real household income is positive and statistically significant for both Beijing and Tianjin, it is marginally significant for Shanghai (10% level) and not significant at all for Chongqing. Interest factor is important only for Tianjin but not other cities. In the case of construction equation, growth rate of the property price is positive and statistically significant for Tianjin, but not significant at all for other cities. The interest factor will positively and significantly affect the growth rate of construction in Tianjin and Chongqing, but negatively and significantly in Beijing and Shanghai. The growth of land price will negatively affect the construction growth in Shanghai, but positively in Tianjin and Chongqing. These results may suggest that cities in China are indeed very different, especially in terms of the stage of economic development and therefore their response to economic environment changes and policy changes may be very different as well. It also cautious us in the application the Panel data approach on Chinese city research which only differentiate cities by a city-level fixed effect term. Future research should try to include a larger set of China cities and "decompose" the cross-city heterogeneity to differences in institutional factors, differences in the economic development or sectoral specialization, among other factors.

While measures such as R^2 may give a sense of the "absolute performance" of the model, we would also like to obtain some measures of "relative performance" of the model. More specifically, we compare both the in-sample-fitting (ISF) and out-of-sample forecast (OSF) of the model with two widely used alternatives, namely, the AR(1) and the random walk. We use both RMSE and AME to establish the robustness. Interestingly, both of our price dynamics equation and our construction dynamics equation out-perform the alternatives in ISF in most cases. In other words, despite their simplicity, both of our price dynamics and construction dynamics capture some important feature of the data during the sampling period 1998 to 2007. For OSF, however, our price dynamics model consistently out-performs the alternatives only in Beijing. Similarly, our construction dynamics model consistently out-performs the alternatives on OSF only in Shanghai. One possibility is that there are changes occur during the year 2008 that our model fails to capture. We will continue to investigate this issue in the future research.

The third major empirical finding is that in both price dynamics and construction dynamics models, the lagged variable are always positive and statistical significant, although the magnitude varies slightly across cities. One interpretation from the literature that this is due to the sluggish adjustment of housing stock, which has been repeatedly documented (among others, see Hanushek and Quigley, 1979; Leung, 2007). Needless to say, it can also be due to information diffusion (as information flow in China is not as efficient as in some Western countries), or policy persistence (as government policy still plays an important role in the housing market). Therefore, this finding also lead to another research agenda, which is to distinguish the causes of persistence in price and construction dynamics, and to identify the role of policy in the dynamic propagation mechanism.

This paper also carries important policy implications. For instance, if the housing market is believed to be "overheating," our results suggest that increasing the interest rate for mortgage loans may not have a significant *direct* effect on bringing down the house price growth in the short run. This is because the housing market of the four cities in the sample period may have been subject to strong speculation or constrained by credit rationing under macro control policy undertaken by the government. In principle, the interest rate may have an *indirect* effect or some general equilibrium effect through its impact on the aggregate output or the stock market. To address this concern, we will need a more elaborate econometric model for the joint estimation of the real estate sector and the aggregate economy, which in turn demands longer time series and more aggregate data.

For another policy application, this paper also shows that the interest rate and the land price change can have very different impacts on the construction across cities. Is it a result of differential local government policies? Or, it is a feature of cities with different stages of economic development or different industrial specialization? To address this question, future research may need to significantly extend the sample size in terms of the number of cities involved. In any case, more investigations of this are clearly needed and the results can be important for both academics and policy makers.

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Table 1a. Summary Statistics of the Variables of Beijing

	Mean	SD	Min	Max
Equation (2.6)				
00Q3 – 08Q4				
GP	3.10	4.39	-6.97	10.10
GR	9.95	24.83	-4.17	92.33
GWAGE	7.96	3.16	1.41	14.68
DU	-0.45	3.32	-6.53	7.50
Equation (2.8)				
98Q2 – 08Q4				
GC	12.96	28.15	-15.10	86.07
GP	2.20	4.30	-6.97	10.10
DTREAL	-0.25	2.94	-6.53	7.50
GLPI	1.49	3.80	-6.67	12.97

Table 1b. Summary Statistics of the Variables of Tianjin

	Mean	SD	Min	Max
Equation (2.6)				
00Q3 – 08Q4				
GP	3.28	3.89	-4.00	13.70
GR	0.28	5.50	-5.83	16.03
GWAGE	8.68	4.62	-0.59	16.47
DU	-0.94	2.55	-7.80	4.63
Equation (2.8)				
98Q2 – 08Q4				
GC	17.97	19.72	-16.95	68.39
GP	2.92	3.58	-4.00	13.70
DTREAL	-0.57	2.54	-7.80	4.63
GLPI	4.94	10.50	-21.23	52.83

Table 1c. Summary Statistics of the Variables of Shanghai

	Mean	SD	Min	Max
Equation (2.6)				
00Q3 – 08Q4				
GP	6.26	8.79	-4.17	27.9
GR	1.67	2.95	-8.37	6.77
GWAGE	7.51	4.05	-3.86	13.57
DU	-0.02	2.74	-4.83	7.17
Equation (2.8)				
98Q2 – 08Q4				
GC	6.28	21.02	-25.07	57.07
GP	3.91	9.13	-8.17	27.9
DTREAL	-0.47	3.48	-9.47	7.17
GLPI	2.56	10.36	-22.93	28.60

Table 1d. Summary Statistics of the Variables of Chongqing

	Mean	SD	Min	Max
Equation (2.6)				
00Q3 – 08Q4				
GP	3.59	4.31	-5.33	13.90
GR	-0.51	3.23	-7.37	4.40
GWAGE	7.03	7.52	-10.20	17.63
DU	-0.99	3.58	-8.10	6.26
Equation (2.8)				
98Q2 – 08Q4				
GC	23.73	27.38	-11.17	117.54
GP	4.11	4.11	-5.33	13.90
DTREAL	-0.68	3.69	-8.10	6.51
GLPI	3.47	6.47	-2.27	32.90

Table 2a. Correlations of the Explanatory Variables of Beijing

Equation (2.6)			
00Q3 – 08Q4			
	GR	***GWAGE***	***DU***
GR	1.00		
GWAGE	-0.38	1.00	
DU	-0.33	0.54	1.00
Equation (2.8)			
98Q2 – 08Q4			
	GP	***DTREAL***	***GLPI***
GP	1.00		
DTREAL	0.21	1.00	
GLPI	0.83	0.21	1.00

Table 2b. Correlations of the Explanatory Variables of Tianjin

Equation (2.6)			
00Q3 – 08Q4			
	GR	***GWAGE***	***DU***
GR	1.00		
GWAGE	-0.30	1.00	
DU	0.28	0.08	1.00
Equation (2.8)			
98Q2 – 08Q4			
	GP	***DTREAL***	***GLPI***
GP	1.00		
DTREAL	0.35	1.00	
GLPI	0.31	-0.04	1.00

Table 2c. Correlations of the Explanatory Variables of Shanghai

Equation (2.6)			
00Q3 – 08Q4			
	GR	***GWAGE***	***DU***
GR	1.00		
GWAGE	0.41	1.00	
DU	0.19	-0.40	1.00
Equation (2.8)			
98Q2 – 08Q4			
	GP	***DTREAL***	***GLPI***
GP	1.00		
DTREAL	0.10	1.00	
GLPI	0.80	0.24	1.00

Table 2d. Correlations of the Explanatory Variables of Chongqing

Equation (2.6)			
00Q3 – 08Q4			
	GR	***GWAGE***	***DU***
GR	1.00		
GWAGE	-0.05	1.00	
DU	0.53	0.46	1.00
Equation (2.8)			
98Q2 – 08Q4			
	GP	***DTREAL***	***GLPI***
GP	1.00		
DTREAL	0.22	1.00	
GLPI	0.18	0.07	1.00

Table 3. Estimation Results of Equation (3) for Beijing, Tianjin, Shanghai and Chongqing

$$GP_t = \varphi[\gamma_1 GR_t + \gamma_2 GWAGE_t + \gamma_4 DU_t] + (1-\varphi)GP_{t-1}$$

	Beijing	Tianjin	Shanghai	Chongqing
Estimation Method	OLS	OLS	OLS	OLS
Dependent Variable	Real Growth Rate of Property Price Index	Real Growth Rate of Property Price Index	Real Growth Rate of Property Price Index	Real Growth Rate of Property Price Index
Real Growth Rate of Rental Price Index	-0.01 (0.60)	-0.06 (0.20)	-0.21 (0.42)	0.57 (0.11)
Real Growth Rate of Household Income	0.11 (0.00)***	0.19 (0.01)***	0.16 (0.09)*	0.09 (0.26)
Annual Difference of User Cost of Homeownership	0.13 (0.16)	0.40 (0.00)***	0.26 (0.30)	-0.28 (0.26)
Lag of the Real Growth Rate of Property Price Index	0.88 (0.00)***	0.73 (0.00)***	0.90 (0.00)***	0.69 (0.00)***
R^2	0.91	0.85	0.81	0.59
Adj. R^2	0.90	0.83	0.79	0.55
Number of Observation	30	30	30	30
Data Range	00Q3 – 07Q4	00Q3 – 07Q4	00Q3 – 07Q4	00Q3 – 07Q4

Notes: 1. All models are *adjusted for heteroskedasticity and autocorrelation* by the Newey-West HAC Standard Errors and Covariance.
2. Numbers in brackets represent the p-value
3. *** significant at 1%; ** significant at 5%; * significant at 10%

Table 4a. Root Mean Squared Error (RMSE) of In-Sample-Fitting of Equation (3), AR(1) Model and Random Walk Model for Beijing, Tianjin, Shanghai and Chongqing (00Q3 – 07Q4)

City	Equation (3)	AR(1)	Random Walk
Beijing	1.37	1.58	1.65
Tianjin	1.51	2.04	2.12
Shanghai	3.86	3.89	4.06
Chongqing	2.67	2.92	3.18

Table 4b. Mean Absolute Error (MAE) of In-Sample-Fitting of Equation (3), AR(1) Model and Random Walk Model for Beijing, Tianjin, Shanghai and Chongqing (00Q3 – 07Q4)

City	Equation (3)	AR(1)	Random Walk
Beijing	1.09	1.25	1.29
Tianjin	1.17	1.47	1.62
Shanghai	3.10	3.10	3.28
Chongqing	2.15	2.08	2.28

Table 4c. Root Mean Squared Error (RMSE) of Out-of-Sample Forecast of Equation (3), AR(1) Model and Random Walk Model for Beijing, Tianjin, Shanghai and Chongqing (08Q1 – 08Q4)

City	Equation (3)	AR(1)	Random Walk
Beijing	1.96	2.65	2.40
Tianjin	3.06	1.25	0.99
Shanghai	2.91	3.04	2.19
Chongqing	3.74	3.89	3.57

Table 4d. Mean Absolute Error (MAE) of Out-of-Sample Forecast of Equation (3), AR(1) Model and Random Walk Model for Beijing, Tianjin, Shanghai and Chongqing (08Q1 – 08Q4)

City	Equation (3)	AR(1)	Random Walk
Beijing	1.71	2.62	2.38
Tianjin	2.89	1.08	0.9
Shanghai	2.09	2.73	1.86
Chongqing	2.43	2.66	2.51

Table 5. Estimation Results of Equation (9) for Beijing, Tianjin, Shanghai and Chongqing

$$GC_t = \delta_1 + \delta_2 GP_t + \delta_3 DTREAL_t + \delta_4 GLPI_t + \delta_5 GC_{t-1}$$

	Beijing	Tianjin	Shanghai	Chongqing
Estimation Method	OLS	OLS	OLS	OLS
Dependent Variable	Growth Rate of Residential Commodity Building Started	Growth Rate of Residential Commodity Building Started	Growth Rate of Residential Commodity Building Started	Growth Rate of Residential Commodity Building Started
Constant	0.51 (0.82)	1.08 (0.71)	-0.21 (0.84)	7.42 (0.15)
Real Growth Rate of Property Price Index	0.04 (0.93)	0.99 (0.03)**	-0.001 (0.99)	-0.36 (0.32)
Annual Difference of Real Lending Rate	-1.47 (0.00)***	1.97 (0.00)***	-1.45 (0.00)***	1.74 (0.05)*
Real Growth Rate of Land Price Index	-0.56 (0.29)	0.11 (0.08)*	-0.18 (0.09)*	0.27 (0.06)*
Lag of the Growth Rate of Residential Commodity Building Started	0.92 (0.00)***	0.73 (0.00)***	0.98 (0.00)***	0.72 (0.00)***
R^2	0.95	0.74	0.93	0.80
Adj. R^2	0.94	0.71	0.92	0.78
Number of Observation	39	39	39	39
Data Range	98Q2 – 07Q4	98Q2 – 07Q4	98Q2 – 07Q4	98Q2 – 07Q4

Notes: 1. All models are adjusted for heteroskedasticity and autocorrelation by the Newey-West HAC Standard Errors and Covariance.
2. Numbers in brackets represent the p-value
3. *** significant at 1%; ** significant at 5%; * significant at 10%

Table 6a. Root Mean Squared Error (RMSE) of In-Sample-Fitting of Equation (9), AR(1) Model and Random Walk Model for Beijing, Tianjin, Shanghai and Chongqing (98Q2 – 07Q4)

City	Equation (9)	AR(1)	Random Walk
Beijing	6.49	8.23	8.38
Tianjin	10.38	12.79	14.19
Shanghai	5.77	8.20	8.32
Chongqing	12.09	13.51	15.78

Table 6b. Mean Absolute Error (MAE) of In-Sample-Fitting of Equation (9), AR(1) Model and Random Walk Model for Beijing, Tianjin, Shanghai and Chongqing (98Q2 – 07Q4)

City	Equation (9)	AR(1)	Random Walk
Beijing	4.99	5.08	5.34
Tianjin	7.07	8.44	8.16
Shanghai	4.14	4.73	4.80
Chongqing	8.11	8.03	8.86

Table 6c. Root Mean Squared Error (RMSE) of Out-of-Sample Forecast of Equation (9), AR(1) Model and Random Walk Model for Beijing, Tianjin, Shanghai and Chongqing (08Q1 – 08Q4)

City	Equation (9)	AR(1)	Random Walk
Beijing	3.49	3.14	2.84
Tianjin	7.44	3.75	4.22
Shanghai	9.79	12.68	12.51
Chongqing	16.60	12.10	10.25

Table 6d. Mean Absolute Error (MAE) of Out-of-Sample Forecast of Equation (9), AR(1) Model and Random Walk Model for Beijing, Tianjin, Shanghai and Chongqing (08Q1 – 08Q4)

City	Equation (9)	AR(1)	Random Walk
Beijing	2.67	3.06	2.72
Tianjin	7.09	3.66	3.75
Shanghai	9.50	12.61	12.35
Chongqing	14.06	11.92	9.24

Appendix I: A more general model of house price

This section attempts to provide a (slightly) more general model of city level house price, which would provide some guidance for our empirical investigation. Following the consumption-based house price model of Kan et al (2004), Leung (2003, 2007), we assume that there is a representative consumer in a city, which maximize the lifetime utility $\max \sum_{t=0}^{\infty} \beta^t U\left(C_t, H_t\right)$, subject to the budget constraint in each period, with $\beta \in (0,1)$ is the discount factor, C_t represents the level of non-durable consumption and H_t the housing stock in the utility function. In this appendix, we do *not* restrict the utility function U to be separable in C and H. The Bellman equation for the dynamic optimization can be written as

$$V\left(H_t; W_t, P_t, P_{t-1}, R_t\right) = \max U\left(C_t, H_t\right) + \beta V\left(H_{t+1}; W_{t+1}, P_{t+1}, P_t, R_{t+1}\right)$$

subject to the budget constraint,

$$W_t + P_t H_t^s \geq C_t + \gamma P_t H_{t+1}^s + \left(1-\gamma\right) R_t P_{t-1} H_t^s + R_t^h H_t^r, \qquad (1)$$

where W_t is the wage, P_t is the per unit house price, H_t^s is the stock of housing purchased in the previous period and owned in the current period, γ is the down-payment ratio, and R_t is the interest factor imposed on the mortgage carried from period (t-1) to period t, R_t^h is the rent for rental housing, H_t^r is the amount of rental housing for the current period. For simplicity, we simply assume that the consumer treats the owner-occupied housing H_t^s and rental housing H_t^r as perfect substitute.

$$H_t = H_t^s + H_t^r$$

Following the method in Kan et al (2004), the first order conditions are easy to derive,

$$\lambda_t = U_{Ct},$$

$$\lambda_t R_t^h = U_{Ht},$$

$$\lambda_t \gamma P_t = \beta \left\{ U_{H,(t+1)} + \lambda_{t+1} \left[P_{t+1} - \left(1-\gamma\right) R_{t+1} P_t \right] \right\},$$

where

$$U_{X,t} = \frac{\partial U\left(C_t, H_t\right)}{\partial X_t}, X = C, H \ .$$

Combining these equations and after some algebraic manipulations, we have

$$\frac{P_{t+1}}{P_t} = \left(\frac{\gamma}{\beta}\right)\left(\frac{R_{t+1}^h}{R_{t+1}^h}\right)\left(\frac{U_{H,t}}{U_{H,(t+1)}}\right) - \left(\frac{1}{P_t}\right)\left(\frac{U_{H,(t+1)}}{U_{C,t}}\right) + \left(1-\gamma\right)R_{t+1} \, .$$

Clearly, the growth of property price would still relate to the growth of house rental rate. On the other hand, the other variables may have much more non-linear relationship with the growth rate of the property price. For instance, the term $\left(\frac{U_{H,(t+1)}}{U_{C,t}}\right)$ depends on both the level of non-durable consumption and amount of residential housing in both period *t* and *(t+1)*, which is very difficult to directly capture in empirical implementation.