An Empirical Study on Housing Supply in Chinese Central Cities: Using the Urban Growth Model

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ABSTRACT

This article considers housing supply under a context of urban growth. Using panel data for five central Chinese cities, from the year 2001 to 2010, this paper employs the urban growth model to find out the determinants in affecting housing supply elasticities variation across cities. The calculation for supply elasticity of housing shows that it is higher for Chongqing city while it is lower for Tianjin city which is closely followed by Beijing. The empirical results also show that urban characteristics have significant affections on housing supply. Urban land use regulation plays a more important role rather than housing price changes in affecting housing supply across cities, which give us an implication for government policy that we can regulate housing outputs through land market.

KEY WORDS: housing supply elasticity, urban growth, housing prices, central city

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1. Introduction

In China, the supply of land which is the main input of housing is controlled by local government, making the area differentiation especially cities differentiation in housing supply. In addition, the different level of economic development, demographic factors as well as diverse city's strategic orientation makes significant difference in supply elasticities across cities in China. Recent papers such as John L. Goodman (1998) and earlier literature such as Raymond J. Struyk (1977) argue forcefully that supply conditions of housing vary from city to city within the country. Despite the plausibility of city differences in supply responsiveness, little has been done to examine such variation directly in China except for recent work by Yuming Fu, Siqi Zheng and Hongyu Liu (2010). They use the structural approach based on the investment theory to estimate the supply elasticity across the cities in China. However, land use regulations and housing market climate are still not fully considered.

The main focus of this paper is on the examination of the variation in housing supply elasticity across cities and trying to explain it. We consider housing supply in the context of urban dynamic growth making our study differ from the existing studies focus on Chinese housing supply. The urban growth model is employed which is most appropriate for single large cities, although most of the empirical studies that follow use national level data. Using the data from five central Chinese cities: Beijing, Tianjin, Shanghai, Guangzhou, and Chongqing, we first calculated the housing supply elasticities for each city, and then examine source of variations in housing supply across cities with consideration of different urban market climate. The results of the first stage show that supply elasticity of housing is higher for Chongqing while Tianjin has a lower significant housing supply elasticity which is closely
followed by Beijing. The empirical results show that urban characteristics have significant affections on housing supply. The coefficients of the estimates of density, space of urban built up areas, land use regulations give us expected signs. The more densely populated city, the more difficult to conduct new constructions, the larger area of urban built up the more housing supply are provided. As an addition, a city with a strict land use regulation will lead to a fewer housing supply. However, one surprise to us is that housing price changes do not have a significant affection on housing supply among the cities, the result of which is different from other studies. Urban land use regulation plays a more important role rather than housing price changes in affecting housing supply across cities, which give us an implication for government policy that we can regulate housing outputs through land market.

In the next chapter, we will briefly describe previous researches. Chapter 3 is the theoretical basis, following that is the chapter 4 which reports the data used and empirical analysis. Chapter 5 concludes the paper with the important findings and the expected future study.
2. Previous Researches

Two approaches (the reduced-form and the structural approaches) are well used to estimate the relationship between the output and housing price. In the first approach, housing supply and demand functions are combined into a single reduced form equation. The price elasticity of outputs is derived form the coefficients on supply and demand shifters in the reduced form regression. Earlier empirical studies on housing supply tend to use this kind of approach, represented by Muth (1960), Follain (1979), Stover (1986), Olsen (1989), Mayo and Sheppard (1996), Malpezzi and Maclellan (2001). Although most of these researches failed to reject the hypothesis that housing supply is perfectly elastic and thus they concluded that the supply curve for new housing is perfectly elastic. Recall to these earlier studies, it is obvious to find that the data used are usually national level data, and the objects of these studies are generally developed countries represented by U.S. and UK.

However, as Dipasquale (1999) pointed out that there have been several attempts to directly model housing supply recently. The theoretical underpinnings of much of this literature come from one of two sources: the investment literature or the literature on urban spatial theory. The main difference in these two approaches lies in the treatment of land which is the most important inputs during producing houses (Denise Dipasquale, 1999). The studies based on investment usually treating land the same as other inputs such like capital, labor tend to ignore the special characteristic of land. Meanwhile, the studies based on urban spatial theory explicitly incorporate the land market into the theoretical structure. In this approach, land is treated different from other common inputs as the supply of it is not unlimited even in the long-run.
Saks et.al (2005) argue that it is impossible to understand many aspects of urban dynamics without understanding housing supply, and that it is difficult to think sensibly about real estate in many context without understanding the urban equilibrium which determines the price and quantity of housing.

Capozza and Helsley (1989) develop a simple model in which capital is durable and landowners have perfect foresight, the price of urban land has four additive components: the value of agricultural land rent, the cost of conversion, the value of accessibility, and the value of expected future rent increases. Land is developed when rent in the urban use equals the opportunity cost of land plus the opportunity cost of conversion capital. At the border of city there is no difference in profit between converting to urban use and keeping agriculture use.

Mayer and Somerville (2000) estimate a supply equation for new single-family residences that is based on the theoretical models of land development and urban growth. Housing starts only happen at the fringe of the city; as a result city increases in size to accommodate new residents when there is a shock of demand increase. This article treats housing starts as the function of the change in construction costs as well as prices rather than the level of these variables. The empirical model in this paper also generates a stable measure of the true supply elasticity, the percentage in the housing stock from a percentage change in house prices. Their estimates suggest a fairly moderate response of supply to house price changes, indicates that a 10% rise in real prices leads to a 0.8% increase in the housing stock, which is accomplished by a temporary 60% increase in the annual number of starts, spread over four quarters. However, the urban growth model is more ideal for estimating housing supply functions for individual metropolitan areas.
Green, Malpezzi and Mayo (1999) extend the work Capozza and Helsely (1989), Mayer and Somerville (2000) and obtain a measure of housing supply elasticity which is related to urban population, interest rate, house prices, urban growth rate and urban density. The work is divided into two stages. In the first stage, they estimate housing supply elasticities for 44 US Metropolitan Statistical Areas (MSAs). In the second stage, they conduct a cross-sectional regression with housing supply elasticities for 44 cities obtained in the last stage as the dependent variable. The estimates of first stage show that there is a huge variation (from -0.3 to 29.9) in housing supply elasticities across cities. The results of second stage show that regulation and density perform well in explaining variation in elasticities across cities, while growth rate and city size does not perform as previously expected.

Mayer and Somerville (2000) incorporate land use regulations into their framework, and present a theoretical framework to describe the relationship between land use regulation and new residential construction. They perform empirical estimates using quarterly data on a panel of 44 metro areas from 1985 to 1996 and find that land use regulations have significant effects in lowering the steady-state level of new construction and reducing the responsiveness of local supply to price shocks (the estimated price elasticity). Their estimates also show that means starts can be up to 45 percent lower in cities that have more extensive regulation. In addition, metro areas with greater regulation have price elasticities that are more than 20 percent lower than in cities with less regulation. A comparison between their local area supply function and a similarly specified national supply function which is well employed in existing researches reveals that the aggregated national data may slightly overestimate the price elasticity of new construction and underestimate the time required to respond to price shocks.
Braid (2001) extends the urban growth model by taking land redevelopment and housing deterioration into account, and develop a method for deriving perfect-foresight spatial growth paths for an urban area, under the closed-city (or open-city) assumption, when the housing at any location can be redeveloped many times. The spatial growth model in this paper uses simplifying assumptions. These include Cobb-Douglas utility and production functions, and constant exponential growth rates for exogenous variables such as per capita income, commuting costs per mile, the construction cost index, and the urban area’s population. Also, agricultural land rents must grow at a certain rate relative to other exponential growth rates. Computer simulation for growth with myopic expectations is also conducted and the results show significant differences between myopic growth and perfect-foresight growth.

The literatures using the structural model are generally based on the theory of investment and urban spatial theory. The biggest difference between the two types of structural model is on the treatment of land which is one of the inputs in producing housing. The structural model based on investment usually treats land the same as other input such like capital, labor. Meanwhile, the model based on urban spatial theory includes land into the model, as the land is different from housing common inputs. Since even in the long-run land supply is not unlimited, it is inappropriate to treat it as common cost variables.
3. Deductive Inference from Mayer and Somerville’s Model

The topmost breakthrough of Capozza and Helsley (1989) and Mayer and Somerville (2000), and some other studies are that they consider urban growth and housing supply together, it is a dramatic, because as argued by Glaeser, Gyourko and Sks: it is impossible to understand housing supply without understanding the urban equilibrium which determines the price and quantity of housing.

The previous work of Mayer and Somerville (2000) shows that a one-time increase in demand in a larger city results in a huge gap between housing demand and housing supply. New construction should be started to accommodate these additional households which moves the housing stock from one equilibrium to another following a positive demand shock. In the mono-concentric models of urban growth this type of shock generates a permanent increase in land and house prices at all interior locations of the city since land within a given distance to the city is in limited supplied unlike other factors such as: capital, materials, and labor which have perfectly elastic supply curves in the long-run.

Based on the model of Capozza and Helsley (1989) and Mayer and Somerville (2000), which assumes developers are perfectly foresight and they can maximize their profits by choosing the best construction time $t^*$ (time to convert agriculture land to urban use). They can smooth their products by delaying the period of construction time to get maximized profits according their expectation of the price changes in the future. Land redevelopment is ignored. (More details in appendix)

At time $t$, the price of a house located at a distance of $d$ can be describes as a function of urban size, interest rate, transport costs, urban growth rate, structural costs, as follows:
\[
hp = \frac{r_a}{l} + c_h + \frac{k(b_r - d)}{i} + \frac{kb_r g}{i(i - g)} \tag{1}
\]

We rearranged the above equation, instead of treating housing price as a function of urban size, we treat urban size as a function of housing price.

\[
b_r = (i - g)\left[\frac{P_h(d, T) - c_h}{k} - \frac{r_a}{ki} + \frac{d}{i}\right] \tag{2}
\]

Assume there are no undeveloped land interior of the city, land redeveloped is also ignored, each resident takes up a space of \(L\) housing, then equilibrium house stock in a monocentric city with \(2\phi\) radians can be developed for residential construction use can be calculated by the following equation:

\[
N(t) \cdot L = \frac{1}{2} \cdot 2\phi \cdot b_r^2 \tag{3}
\]

If we add the assumption that urban city grows exponentially at a constant rate \(g\), the housing stock thus can be described as function (4)

\[
\Delta HS = N(t) \cdot L = f(p, i, g, k, d) \tag{4}
\]

Then, we can derive our empirical model from function (4) and consider housing supply with urban growth and urban characteristics. In this paper, since what we will consider is housing supply difference across five central Chinese cities: Beijing, Tianjin, Shanghai, Guangzhou, Chongqing, the interest rate is abandon as there are no difference in it across cities. As our focus is on the variation in housing supply elasticities and it sources from urban characteristics differences, we will first observe housing supply elasticity across cities. We finally design our basic empirical model to examine housing supply determinants for cities with housing outputs changes as explained variable and include density, urban population, urban size, and urban land regulation as explanatory variables. Our empirical model is described as follows:
\[ \Delta hs_{it} = a_i + \beta_1 \Delta hp_{it} + \beta_2 \text{density}_{it} + \beta_3 \Delta pop_{it} + \beta_4 \text{lp}_{it} + \beta_5 \text{urban}_{it} + \beta_6 \text{ls}_{it} + u_{it}, \]

where \( i \) is denoted different cities and \( t \) is the time.

Housing stock in this article is derived from the space of housing per resident multiplied by urban population to measure housing supply. Completions of new residential constructions are treated as a flow of housing outputs. We will calculate housing supply elasticities using both the stock and flow of housing outputs.
4. Data and Empirical Analysis

The panel data are assembled for five central cities: Beijing, Tianjin, Shanghai, Guangzhou, and Chongqing, from the year of 2001 to 2010. Data were only available on an annual basis. Table 1 reports the main indicators appear in this paper. We first estimates housing supply elasticities for each city in two ways and then examine the variation across cities and different years. In the next step we conduct regressions to find out the determinants in affecting housing supply across cities. Our focus is on the test that whether variations in urban characteristics is the main cause of discrepancies of housing supply among different cities. For each of the five cities, we need observations of housing prices, housing outputs, land supplied for housing construction and some other observations for urban characteristics, such as density, urban built up areas and urban populations. The main data sources are listed at the end of this paper and also the measure of the outputs of housing and housing prices.

(1). The estimates of elasticity of housing supply $\eta_i$

Table 2 reports the point elasticities for each city from the year 2001 to the year 2010. Two measures for changes of housing output are used in calculations. $\eta_1$ is calculated by percentage changes in housing stocks divided by percentage changes in housing prices, while $\eta_2$ is obtained from the ratios of the percentage changes in housing stocks to the percentage changes in housing prices. By doing this, we can observe the trend of housing supply elasticities during the period of the year 2001 to 2010 across different cities. And it is also clear that if different measures for housing output used is a problem which will lead to

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* National central city was a concept proposed by the Ministry of Housing and Urban-Rural Development of the People’s Republic of China in 2005, it was described as a group of cities in charge of leading, developing, performing tasks in political, economic, and cultural aspects. In February 2010, the ministry issued the “National Urban System Plan” and designated five major cities, Beijing and Tianjin, Shanghai, Guangzhou, and Chongqing in western China as national central cities.
variation in housing supply elasticities calculation. For Beijing city, \( \eta_1 \) varies from -20.69 to 2.99 and \( \eta_2 \) varies from -32.58 to 10.75; for Tianjin city, \( \eta_1 \) varies from 0.09 to 36.50 and \( \eta_2 \) varies from 0.07 to 16.80; for Shanghai city \( \eta_1 \) varies from -3.74 to 1.43 and \( \eta_2 \) varies from -0.48 to 20.66; for Guangzhou city \( \eta_1 \) varies from -10.08 to 1.62 and \( \eta_2 \) varies from -16.33 to 2.19; for Chongqing city \( \eta_1 \) varies from 0.07 to 3.76 and \( \eta_2 \) varies from -0.36 to 5.21.

Table 2: Housing Supply Elasticity: \( \eta_i \)

(i for cities,  \( t \) for time)

<table>
<thead>
<tr>
<th>year</th>
<th>Housing supply elasticity (point elasticity)</th>
<th>( \eta_1 )</th>
<th>( \eta_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( i = Beijing )</td>
<td>( i = Tianjin )</td>
<td>( i = Shanghai )</td>
</tr>
<tr>
<td></td>
<td>(percentage changes in housing stocks/percentage changes in housing prices)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( t = 2001 )</td>
<td>2.988461</td>
<td>36.49621</td>
<td>0.985379</td>
</tr>
<tr>
<td>( t = 2002 )</td>
<td>-1.17456</td>
<td>1.087174</td>
<td>0.79953</td>
</tr>
<tr>
<td>( t = 2003 )</td>
<td>-20.697</td>
<td>0.283832</td>
<td>0.35071</td>
</tr>
<tr>
<td>( t = 2004 )</td>
<td>0.717007</td>
<td>1.481568</td>
<td>0.739457</td>
</tr>
<tr>
<td>( t = 2005 )</td>
<td>0.222963</td>
<td>0.088942</td>
<td>0.48491</td>
</tr>
<tr>
<td>( t = 2006 )</td>
<td>0.403255</td>
<td>0.457912</td>
<td>1.425771</td>
</tr>
<tr>
<td>( t = 2007 )</td>
<td>0.133568</td>
<td>0.384156</td>
<td>0.484012</td>
</tr>
<tr>
<td>( t = 2008 )</td>
<td>0.44147</td>
<td>27.71585</td>
<td>-3.73751</td>
</tr>
<tr>
<td>( t = 2009 )</td>
<td>0.279333</td>
<td>0.523317</td>
<td>0.097129</td>
</tr>
<tr>
<td>( t = 2010 )</td>
<td>0.067011</td>
<td>0.529949</td>
<td>0.384956</td>
</tr>
</tbody>
</table>

| year | Housing supply elasticity (point elasticity) | \( \eta_2 \) | |
|------|--------------------------------------------|-----------|
|      | (percentage changes in housing completions/percentage changes in housing prices) | |
| \( t = 2001 \) | 10.74507 | 20.0126 |
| \( t = 2002 \) | -7.24917 | 1.595474 |
| \( t = 2003 \) | -32.5826 | 0.731254 |
| \( t = 2004 \) | 1.936049 | 6.322555 |
| \( t = 2005 \) | 0.712027 | 0.115173 |
| \( t = 2006 \) | -1.15845 | 0.180038 |
| \( t = 2007 \) | -0.3473 | 0.343732 |
| \( t = 2008 \) | -2.64959 | 16.80313 |
| \( t = 2009 \) | 1.129942 | 0.328806 |
| \( t = 2010 \) | -0.23953 | 0.071452 |

Note. Changes to the corresponding period last year is used in calculations. Housing stocks are obtained by the per-capita living space of urban residents multiplied by urban population.
We also do regressions based on \( \hat{n} = \alpha + \beta_1 \hat{p} + \beta_2 \hat{p}(-1) \), a stable measure of housing supply elasticities following the work of Dennis R. Capozza and Robert W. Helsley (1989), Green, Malpezzi and Mayo (1999), Christopher J. Mayer and C. Tsuriel Somerville (2000). We do five regressions for five cities directly with two different measures of housing outputs changes and with price changes lagged once. The results are presented in Table 4.

We calculate housing supply elasticity for five cities using housing completions as a measure of housing output, \( \eta_1 \) (HSE1 in figure 1) the results are reported in the second Column in Table 4. \( \eta_2 \) (HES2 in figure 1) is the housing supply elasticity using housing stock as the measure of housing outputs.

![Figure 1. Housing Supply Elasticity Ranking: Five Central Chinese Cities.](image)

In order to get an intuitive understanding, we rank the estimates of HSE1 and HSE2 in Figure 1. When we examine the variation of the supply elasticity across the five cities, it is easy to find that it range from 0.61 to 3.66 for HSE1 and 0.52 to 1.83 for HSE2. The supply elasticity is most significantly highest in Chongqing no matter for HSE1 and HSE2. Tianjin has a lower significant HSE estimates and closely followed by Beijing. The biggest difference in magnitude of housing supply elasticity is the HSE for Shanghai, which is calculated to less
than 0 for HSE1 and HSE2 (see the Second and Third Columns in Table 1), while a significantly estimate of 0.848 is calculated by using housing stock as a measure of housing output.

Recall to the previous studies focus on estimating housing supply elasticity in China, using national data or urban cities data, our estimates seems higher. Gregory and Linlin Niu (2009) give the price elasticity of supply about 0.83 for the total stock of housing in China. Using panel data from China’s 30 provinces and autonomous regions, Wang Bin and Gao Bo (2010) reports the supply elasticities 0.52, 1.48, 0.75 for eastern, central and western areas respectively. Long Fenjie et.al. (2008) studies the relationship between housing supply and urban growth, and gives housing supply elasticities Beijing (1.36), Tianjin (0.38), Shanghai (0.45), Guangzhou (0.73). The recent research of Yuming Fu et.al. (2010) estimate housing supply elasticities for 85 Chinese cities from 1.46 to 0.62 using more precise approach.

Based on urban economics theory, if a city’s housing supply is relatively elastic, we should expect an outward shift in demand to result in an increase in population, while the corresponding increase in housing prices should be relatively modest (see point A). Even in

\[ \text{Number of Homes and Population} \]

\[ \text{Housing Prices and Wages} \]

\[ \text{Inelastic Supply} \]

\[ \text{Elastic Supply} \]

\[ \text{Old Demand} \]

\[ \text{New Demand} \]

\[ \text{Figure 2. The nature of housing supply and the impacts of demand shock} \]
the face of a major positive demand shock, unfettered new supply should prevent the price of housing from raising much above construction costs. However, if housing supply is inelastic, then positive shocks to urban productivity will have little impact on new construction or the urban population. Because the number of homes does not increase significantly, housing prices must rise (point B).

Figure 3: the nature of housing supply and impacts of housing demand shocks, five cities (Note: be drawn depend on Table 1 and Figure 2.)

In the face of a one-time demand shock, Chongqing, a city with elastic housing supply can provide new supply through new constructions which will prevent housing price rising too much while the housing prices of cities such as Guangzhou, Beijing, Tianjin and Shanghai, which have a less elastic housing supply will growth quickly. Workers are unwilling to live in cities with higher housing price leading to movement of population, results in labor lack and thus the wage should rise. Housing supply elasticity plays an important role in urban dynamics development, which generates an urgent need to doing researches in this area especially for empirical work.

(2). Determinants of Housing Supply

In the former stage, we have compared the variation of housing supply elasticities across
these central cities. In the next stage, we will do regression attempting to examine whether marketplace differences and urban characteristics across cities will lead to affections on $\eta$.

The explanatory variables mainly include housing price changes, population changes, urban expansion, and land use regulation. The data used in this stage is the panel data for five central cities with time span of the year 1996 to 2010. By doing so, we seek to examine the factor which lead to the variation in housing supply elasticities across cities. Our basic estimation model is as follows:

$$\Delta h_{it} = \alpha + \beta_1 \Delta h_{it} + \beta_2 \text{density}_{it} + \beta_3 \Delta \text{pop}_{it} + \beta_4 \text{lp}_{it} + \beta_5 \text{urban}_{it} + \beta_6 \text{ls}_{it} + u_{it}$$

$i$: Five central cities, Beijing, Tianjin, Shanghai, Guangzhou, Chongqing

$t$: Year, 2001-2010

We use the instrument variable, housing completions as a measure of housing stock changes, and it can be treated as a flow of housing stock adjustment. New completions make the housing stock move from one equilibrium to equilibrium, to accommodate new increased housing demand shock. Using this variable will give us a more precise understanding of housing supply dynamics.

The regression results are reported in Table 3. Regr.1-Regr.3 use the estimation method of OLS and the results are reported in corresponding columns. Regr.4-Regr.6 use the estimation method of EGLS (Cross-section Weights (GLS)) with a fixed-effect model. In all cases, the changes in housing prices, $\Delta h_p$ is not significant greater than zero, which is not positive as we expected in advance. It implies that housing supply in Chinese cities is not significantly affected by housing price changes. However, measures of urban characteristics perform well

* Since our focus is on five Chinese national central cities we choose Fixed-effect variable intercept as our estimation method.
in most of the regressions. The coefficients of the estimates of density, space of urban built up areas, land use regulations give us expected signs (using the method of EGLS with fixed-effect estimation model). The variable of urban density shows a significant negative effect on housing supply, as densely populated city makes it more difficult to conduct new constructions. Regr.5 and Regr.6 shows that the variable of urban built up area has a significant positive affect on housing supply, the larger area of urban built up the more housing supply are provided. One of the most important findings of this article is that urban land use regulation plays an important role in affecting housing supply in cities. Two instrument variables are used for measure urban land regulation in our analysis: land purchased in a year by developers and the average land prices for each city. The coefficients of the variable of land price are significant smaller than zero (see the Row.8 in Table 3), which implies that a higher land price will lead to fewer housing supply provided. A city with a strict land use regulation will lead to a fewer housing supply. This result reminds us once again that consider housing supply in a city without taking land regulation into account is not appropriate.
### Table 3

**Housing supply regressions—urban characteristics, housing supply interaction.**

**Dependent Variable:** housing completions

<table>
<thead>
<tr>
<th>Variables and corresponding denotes</th>
<th>Regr.1 Pooled OLS</th>
<th>Regr.2 Pooled OLS</th>
<th>Regr.3 Pooled OLS</th>
<th>Regr.4 EGLS Method Fixed-effect</th>
<th>Regr.5 EGLS Method Fixed-effect</th>
<th>Regr.6 EGLS Method Fixed-effect</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intercept</strong></td>
<td>-1409.52 (473.92)</td>
<td>-938.25 (466.62)</td>
<td>-1140.81 (469.215)</td>
<td>5227.900 (469.215)</td>
<td>5296.802 (469.215)</td>
<td>5449.203 (469.215)</td>
</tr>
<tr>
<td><strong>Change in Housing prices (Δhp)</strong></td>
<td>-0.082 (0.095)</td>
<td>-0.180 (0.092)</td>
<td>-0.029 (0.050)</td>
<td>-0.033 (0.048)</td>
<td>-0.033 (0.048)</td>
<td>-0.033 (0.048)</td>
</tr>
<tr>
<td><strong>Change in Population (Δpop)</strong></td>
<td>11.162 (3.060)</td>
<td>12.911 (3.180)</td>
<td>13.179 (3.277)</td>
<td>6.933 (2.984)</td>
<td>7.133 (3.110)</td>
<td>6.971 (3.025)</td>
</tr>
<tr>
<td><strong>Density (density)</strong></td>
<td>1.353 (0.368)</td>
<td>1.216 (0.388)</td>
<td>1.476 (0.376)</td>
<td>-5.237 (-3.042)</td>
<td>-5.305 (-3.162)</td>
<td>-5.428 (-3.296)</td>
</tr>
<tr>
<td><strong>Urban built up area (urban)</strong></td>
<td>1.955 (0.392)</td>
<td>1.985 (0.417)</td>
<td>2.074 (0.428)</td>
<td>2.458 (0.269)</td>
<td>2.458 (0.269)</td>
<td>2.443 (0.269)</td>
</tr>
<tr>
<td><strong>Land space purchased (ls)</strong></td>
<td>0.428 (0.164)</td>
<td>0.428 (0.164)</td>
<td>0.428 (0.164)</td>
<td>0.013 (0.102)</td>
<td>0.013 (0.102)</td>
<td>0.013 (0.102)</td>
</tr>
<tr>
<td><strong>Land price (lp)</strong></td>
<td>-0.138 (-0.057)</td>
<td>-0.136 (-0.060)</td>
<td>-0.136 (-0.056)</td>
<td>-0.135 (-0.047)</td>
<td>-0.142 (-0.045)</td>
<td>-0.142 (-0.045)</td>
</tr>
<tr>
<td><strong>Number of observations</strong></td>
<td>49</td>
<td>49</td>
<td>49</td>
<td>49</td>
<td>49</td>
<td>49</td>
</tr>
<tr>
<td><strong>R-squared</strong></td>
<td>0.633</td>
<td>0.574</td>
<td>0.536</td>
<td>0.903</td>
<td>0.904</td>
<td>0.904</td>
</tr>
<tr>
<td><strong>D-W statistics</strong></td>
<td>0.953</td>
<td>0.851</td>
<td>0.556</td>
<td>1.325</td>
<td>1.319</td>
<td>1.295</td>
</tr>
</tbody>
</table>

**Intercept correction:**
- Regr.4: Beijing (-1784.96), Tianjin (-1121.75), Shanghai (7769.83), Guangzhou (-482.33), Chongqing (-3603.81)
- Regr.5: Beijing (-1802.83), Tianjin (-1131.98), Shanghai (7834.847), Guangzhou (-477.1201), Chongqing (-3639.44)
- Regr.6: Beijing (-1833.402), Tianjin (-1177.492), Shanghai (8023.699), Guangzhou (-487.930)

**Note.** Standard errors and t statistics are in parentheses, t statistics are italicized. Data are panel data for
the year from 2001 to 2010, five central Chinese cities: Beijing, Tianjin, Shanghai, Guangzhou and Chongqing. Instruments variables used for urban land use regulation are land space purchased by developers in a year and land prices for each city. Density, population, and urban built up areas are used to measure urban characteristics.

* GLS method are used to reduce the effect of heteroscedasticity caused by cross-sectional data used.
5. Implications and Conclusions

We consider housing supply in the context of urban dynamic growth making our study differ from the existing studies focus on Chinese housing supply. Using the data from five central Chinese cities: Beijing, Tianjin, Shanghai, Guangzhou, and Chongqing, we first calculated the housing supply elasticities for each city, and then examine source of variations in housing supply across cities with consideration of different urban market climate. The results of the first stage show that supply elasticity of housing is higher for Chongqing while Tianjin has a lower significant housing supply elasticity which is closely followed by Beijing.

Combining the urban growth model and housing market, it is straightforward that in the face of a one-time demand shock, Chongqing, a city with elastic housing supply can provide new supply through new constructions which will prevent housing price rising too much while the housing prices of cities such as Guangzhou, Beijing, Tianjin and Shanghai, which have a less elastic housing supply will growth quickly. Workers are unwilling to live in cities with higher housing price leading to movement of population, results in labor lack and thus the wage should rise. Housing supply elasticity plays an important role in urban dynamics development.

We also do regressions to examine the source of housing supply variations across cities. The regression results show that urban characteristics have significant affections on housing supply. The coefficients of the estimates of density, space of urban built up areas, land use regulations give us expected signs. The more densely populated city, the more difficult to conduct new constructions, the larger area of urban built up the more housing supply are provided. What more important is that urban land use regulation plays an important role in
affecting housing supply across cities. Two instrument variables are used for measure urban land regulation in our analysis: land purchased in a year by developers and the average land prices for each city. A city with a strict land use regulation will lead to a fewer housing supply. This result reminds us once again that consider housing supply in a city without taking land regulation into account is not appropriate. One surprise is that housing price changes do not have a significant affection on housing supply among the cities, the result of which is different from other studies. Urban land use regulation plays a more important role rather than housing price changes in affecting housing supply across cities, which give us an implication for government policy that we can regulate housing outputs through land market. Further study will conducted using a larger sample of Chinese cities and more precise empirical method.
Note.

The Original Model of Urban Growth

Here, \( z(t) \) is denoted the distance from the border of the city to the city center, \( z \) denotes household location, distance from the city center. Lot sizes are fixed at \( L \) units per household; developers have perfect foresight, no redevelopment and undeveloped residential use land interior of the city.

Assumptions

An urban area is located on a homogeneous plain 2\( \phi \) radians of which are suitable for residential development. At time \( t \in [0, \infty) \) there are \( N(t) \) identical households in the urban area and they derive utility from a composite numeraire good \( X \) and lot size \( L \). The utility function \( U(X, L) \) is homogeneous of degree 1, continuous and increasing in \( X \) and \( L \). We assume lot sizes are fixed at \( L \) units per household. Since the utility function is homogeneous of degree 1 we may write

\[
U(X, L) = L U \left( \frac{X}{L}, 1 \right) = u \left( \frac{X}{L} \right),
\]

where \( u(X / L) \) is continuous and increasing in the ratio of other goods to lot size.

\[
\frac{X}{L} = u^{-1}[v(t)]
\]

Different households live on annular lots at different distance from the central business district (CBD) a point in space at which all non-residential activity takes place. Every day each household commutes to and form CBD to work and shop, and locations are indexed by their distance \( z \) from the CBD. The cost of commuting a unit of distance is a positive constant \( T \). If a household lives at a distance \( z \), he has a commuting cost \( Tz \).
**Land Rent**

At each point land rent $R$ satisfies the budget constraint,

$$y = X + R\bar{L} + Tz,$$  \hspace{1cm} (2)

where $y$ is household income. If the time path of utility is $v(t)$ then the rent function is

$$R(t, z) = (1/\bar{L})(y - Tz) - u^{-1}[v(t)].$$  \hspace{1cm} (3)

What is unknown for us is the time path of utility.

The derivatives of $R(t, z)$ with respect to distance and time are (4) and (5) respectively,

$$R_z(t, z) = -T/\bar{L} < 0$$  \hspace{1cm} (4)

Equation (4) is the familiar spatial equilibrium condition that rent falls with distance to offset rising transportation costs.

and $R_t(t, z) = -u^{-1}[v(t)]v'(t)$  \hspace{1cm} (5)

Equation (5) shows that if income are constant, then lower utility levels accompany rising rents as the urban area grows.

**The Land Price**

If landowners have perfect foresight and the land market is competitive, the price of land equals the present value of expected land rents. We assume the rent of land increasing exponentially. The value at time $t$ of a unit of developed land at location $z$ is

$$P^b(t, z) = \int_t^{\infty} R(\tau, z)e^{-r(\tau-t)} d\tau, t \in [t^*, \infty),$$  \hspace{1cm} (6)

$r$: the discount rate

$t^*$: the date land is converted from agricultural use to develop use.

The value at time $t$ of a unit of agricultural land at location $z$ is

$$P^a(t, z) = \int_0^t Ae^{-r(t-\tau)} d\tau + \int_0^{\infty} R(\tau, z)e^{-r(\tau-t)} d\tau - Ce^{-r(t^*-t)}, t \in [0, t^*),$$  \hspace{1cm} (7)
A: agricultural land rent

C: the cost of converting a unit of land from agricultural use to urban use.

The first term: the present value at time $t$ of agricultural rent up to the conversion day.

The second term: the present value of urban rent from the conversion day onward.

The last term: the present value of the conversion cost at $t^*$. In this model the urban structure, once built, does not depreciate. Redevelopment is unconsidered.

**Conversion Time**

Owners of agricultural land choose a date of conversion $t^*$ to maximize the present value land value given in (7). This equation can be simplified to

$$P^d(t, z) = \int_{t^*}^{\infty} R(\tau, z) e^{-r(\tau-t)} d\tau + (A/r)[1 - e^{-r(t^*-t)}] - Ce^{-r(t^*-t)}. \quad (8)$$

First necessary condition of (8) with respect to $t^*$ is

$$R(t^*, z) = A + rC \quad (9)$$

Land is developed when rent in the urban use equals the opportunity cost of land plus the opportunity cost of conversion capital. Equation (9) implicitly defines the boundary of the urban area at time $t$:

$$R(t, \bar{z}(t)) = A + rC. \quad (10)$$

**Land Market Equilibrium**

Since each household consume a fixed lot size $L$, the land market equilibrium condition is

$$\bar{z}(t) = \left[\frac{N(t)L}{\phi}\right]^{1/2}. \quad (11)$$

Note: $N(t)L = \frac{1}{2} \cdot 2\phi \cdot \bar{z}^2(t) = \phi\bar{z}^2(t)$. Assume the locations of households are close-set.

**Rent function**
The only unknown in the model is the time path of utility $v(t)$.

Equation (10) and (3) imply,

$$v(t) = u[(y/L) - (A + rC) - (T/L)\bar{z}(t)]$$  \hspace{1cm} (12)

which in turn implies that the rent function is

$$R(t, z) = A + rC + (T/L)[\bar{z}(t) - z], \, z \leq \bar{z}(t)$$  \hspace{1cm} (13)

Rent consists of the agricultural rent, plus the rent on the capital used to convert the land to urban use, plus location rent, $(T/L)[\bar{z}(t) - z]$. Beyond $z(t)$ rent equals the agricultural productivity of land,

$$R(t, z) = A, \, z > \bar{z}(t).$$  \hspace{1cm} (14)

**Land prices in the developed area**

To solve for the equilibrium price of developed land we first substitute (13) into (6) which gives

$$P^h(z,t) = \frac{A + rC - T\bar{z}}{r} + T\int_{t}^{\infty} \bar{z}(\tau)e^{-r(\tau-t)}d\tau$$  \hspace{1cm} (15)

$$P^h(t, z) = \frac{A}{r} + C - \frac{T\bar{z}}{r} + \frac{T}{r}\bar{z}(t) + \left(\frac{T}{r}\right)\int_{t}^{\infty} \bar{z}(\tau)e^{-r(\tau-t)}d\tau$$

Assume $\lim_{\tau \to \infty} N(\tau)^{1/2} e^{-\tau} = 0$. Otherwise, the price of developed land is unbounded.

Integrating the mid terms yields,

$$P^h(t, z) = \frac{A}{r} + C + \frac{T}{r}[\bar{z}(t) - z] + \left(\frac{T}{r}\right)\int_{t}^{\infty} \bar{z}(\tau)e^{-r(\tau-t)}d\tau$$  \hspace{1cm} (16)

Or equivalently

$$P^h(t, z) = \frac{A}{r} + C + \frac{k}{r}[\bar{z}(t) - z] + \left(\frac{1}{r}\right)\int_{t}^{\infty} R(\tau, z)e^{-r(\tau-t)}d\tau$$  \hspace{1cm} (17)

The last term in equation (17) indicates the value of future rent increases resulting from urban growth.

City expands in annular to accommodate all the increased households, new construction
occurs only at the fringe of the city. We assume the urban area’s population exponentially at a constant rate $g$:

$$ N(t) = N(0)e^{gt}. \quad (18) $$

From (11),

$$ \bar{z}(\tau) = \bar{z}(t)e^{g(t-\tau)/2} \quad (19) $$

and $r > g/2$

(17) can be written as

$$ P^h(t, z) = A + C + (T/r)[\bar{z}(t) - z] + T \cdot \frac{g/2}{r(r - g/2)} \cdot \bar{z}(t) \quad (20) $$

The final term in (21) is the value of anticipated future rent increase at location $z$ when the urban areas expand exponentially.

Instead of defining prices as a function of city size, we rearrange (20) to express the border as a function of house prices at a fixed interior location $z (z \leq \bar{z}(t))$,

$$ \bar{z}(t) = (r - g/2)[\frac{P^h(z,t) - C}{T} - \frac{A}{Tr} + \frac{z}{r}] \quad (21) $$

g is the speed of the urban expansion.
APPENDIX A:

Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beijing</th>
<th>Tianjin</th>
<th>Shanghai</th>
<th>Guangzhou</th>
<th>Chongqing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (N=5)</td>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
</tr>
<tr>
<td>Completions (10,000 sq.m)</td>
<td>1607.36</td>
<td>1001.97</td>
<td>2153.15</td>
<td>717.27</td>
<td>1350.63</td>
</tr>
<tr>
<td>Housing space per capita (sq.m/person)</td>
<td>19.21</td>
<td>22.99</td>
<td>14.45</td>
<td>17.23</td>
<td>21.33</td>
</tr>
<tr>
<td>Selling price of Housing (yuan/sq.m)</td>
<td>7593.86</td>
<td>3963.20</td>
<td>6509.93</td>
<td>5944.81</td>
<td>1933.79</td>
</tr>
<tr>
<td>Built up area (Sq.km)</td>
<td>16,801.25</td>
<td>11,760.00</td>
<td>7,037.00</td>
<td>82,300.00</td>
<td></td>
</tr>
<tr>
<td>Permanent urban population</td>
<td>11,716,000</td>
<td>6,825,105</td>
<td>12,030,644</td>
<td>7,727,163</td>
<td></td>
</tr>
<tr>
<td>Density (Sq.km)</td>
<td>1,309.4</td>
<td>1,044.4</td>
<td>3,298.3</td>
<td>1,055.0</td>
<td>382.0</td>
</tr>
</tbody>
</table>

*Housing stock*

A measure of housing stock which would reduce error due to the heterogeneous nature of housing is desirable. Two residential output measures: the real value of residential construction in each country and either starts or completions are often used to estimate housing outputs. We have complete data of housing completions and HSP for the five central

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Follain (1979): A measure of the value of the stock of housing: net stocks, lagged one year, including nonfarm dwellings 1-4 units, nonfarm dwellings 5 or more units, farm dwellings, mobile homes (farm and non-farm), no housekeeping buildings, and equipment. Richard K. Green, Stephen Malpezzi and Stephen K. Mayo (1999): Percentage change of housing stock is derived from the number of housing...
cities while the housing starts are only available for Shanghai and Chongqing. Series of housing completions from the year 2002 to 2010 are gathered from the data about the Main Indicators of Real Estate Projects in 35 Large and Medium-sized Cities (China Statistical Yearbook, 2010). Due to the change of statistic system, the data of “per capita residential floor space” for Chongqing and Tianjin before 2002 is the data of “per capita living”. In order to keep series consistent, we convert the living space per capita into HSP for urban residents by dividing 0.75.

**Housing Prices**

Unlike the literatures focuses on developed countries like U.S., which often use repeat sales price index and a hedonic house price series as the price variable in a supply equation, we measure housing prices movements with the average selling price of residential housing in each city, which calculated by dividing the total sales value by the total space housing sold. Although this kind of housing price measure cannot reflect quality improvements in housing stock, a quality-adjusted housing price index or a repeated-sales housing price index is not available for Chinese cities as argued by Liu Hongyu and Shen Yue (2005). However, the work of compilation of housing price index for 35 large and medium-sized cities has been started form the year 2004.

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units for which building permits were issued, multiplied by 2.5, divided by population. Long Fenjie et.al. (2008) uses housing completions while Wang Bin, Gao Bo (2010) uses new starts of residential building to measure the quantity of housing supplied.
APPENDIX B:

Table 4
Housing Supply Elasticity Based Upon Lagged Price Change Once

<table>
<thead>
<tr>
<th>City</th>
<th>(HSE1)</th>
<th>(HSE2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left-hand side:</td>
<td>Left-hand side:</td>
</tr>
<tr>
<td></td>
<td>Housing Completions (flow)</td>
<td>Housing stock (stock)</td>
</tr>
<tr>
<td>Beijing</td>
<td>1.859**</td>
<td>0.578***</td>
</tr>
<tr>
<td></td>
<td>(2.56)</td>
<td>(3.45)</td>
</tr>
<tr>
<td>Tianjin</td>
<td>2.042*</td>
<td>0.798</td>
</tr>
<tr>
<td></td>
<td>(1.95)</td>
<td>(1.24)</td>
</tr>
<tr>
<td>Shanghai</td>
<td>-0.61</td>
<td>0.848**</td>
</tr>
<tr>
<td></td>
<td>(-0.70)</td>
<td>(2.27)</td>
</tr>
<tr>
<td>Guangzhou</td>
<td>0.04</td>
<td>0.52**</td>
</tr>
<tr>
<td></td>
<td>(0.19)</td>
<td>(2.11)</td>
</tr>
<tr>
<td>Chongqing</td>
<td>3.66**</td>
<td>1.83**</td>
</tr>
<tr>
<td></td>
<td>(3.046)</td>
<td>(2.97)</td>
</tr>
</tbody>
</table>

Note. \( \hat{n} = \alpha + \beta_1 \hat{p} + \beta_2 \hat{p}(-1) \), t-statistics are in parentheses; * denotes statistical significance at the 10% level; ** denotes statistical significance at the 5% level; *** denotes statistical significance at the 1% level. Contemporaneous price changes might be determined simultaneously with housing stock changes, and therefore regression with contemporaneous price changes as explanatory variables might produce biased coefficients. Thus, we perform regressions with once lagged changes of housing price. However, considering the series we used is somewhat short, the length of period lagged was decided to one year referring to the previous study of Mayer and Somerville (2000).
APPENDIX C:

List of Data Source

(http://www.stats.gov.cn/tjsj/ndsj);


City Statistic Yearbook, 2011;

Shanghai Real Estate Statistic Yearbook, 1999-2008;


Chongqing Statistical Yearbook 2011, Statistical Information of Chongqing,
(http://www.cqti.gov.cn/html/tjsj/tjnj/);

Guangzhou Statistical Information network
(http://data.gzstats.gov.cn/gzStat1/chaxun/njsj.jsp);

Beijing Statistical Yearbook 2011,

China Statistic Data, (http://www.china.org.cn/e-company/)

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Green, Melpezzi, and Mayo: “Metropolitan-specific estimates of the price elasticity of supply of housing, and their sources”.


