Regional Housing Supply Elasticity in China 1999-2013: A Spatial Equilibrium Analysis

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by

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Abstract

In this paper, we apply a spatial equilibrium growth model (Glaeser and Tobio, 2008) to examine relative housing price growth across the provinces and municipalities of mainland China for 1999-2013. The spatial equilibrium growth model is built upon the traditional static Rosen-Roback spatial equilibrium model. A distinguishing feature is the addition of a regionally-varying elasticity of housing supply. A primary finding is the significant geographical differences in housing price growth and the importance of differences in regional housing supply in explaining the differences in housing price growth. Regions in the East had the most inelastic housing supply, while northern regions had the most elastic housing supply.

1. Introduction

The housing sector in China has undergone significant transformations in first becoming privatized with reforms in 1988 and then becoming market-based with the 1998 reforms (Ye et al., 2010; Man et al., 2011). The move to a market-based housing sector was accompanied by rapid urbanization and growth of housing supply. Across provinces and municipalities, housing prices on average more than tripled. Studies on regional housing markets in China have identified numerous determinants of regional and urban housing price increases (e.g., Yu, 2011; Hanink et al., 2012; Bian, 2013; Huang, 2014; Wang and Zhang, 2014). Variables identified in the studies include availability of credit, construction costs, housing policies, housing price bubbles, income, land supply, population, preferences for housing, and tax treatment.

Empirically identifying all the factors affecting housing prices is difficult. Some factors affect the demand for housing, while others affect housing supply. In this paper, we use a spatial equilibrium growth model (Glaeser and Tobio, 2008) to estimate the differences in housing supply across mainland China (i.e., excluding Hong Kong and Macao) over the period of 1999 to 2013. The model separates changes in housing demand arising from shocks to firm and household attractiveness from exogenous changes to housing supply. We then examine geographic patterns in the differences in housing supply elasticity for the provinces and municipalities. We also estimate the proportions of relative housing price changes attributable to housing supply differences across China's regions.

We briefly discuss the literature on incorporating housing supply into regional growth analysis in the next section. Section 3 presents the theoretical framework of the model and derives the expression for shocks to regional housing supply and the expression for their effects on regional housing prices. Section 4 presents and discusses empirical implementation of the model for the provinces and municipalities in China. Section 5 discusses the findings of the analysis. A primary finding is the significant geographical differences in housing price growth and the importance of differences in regional housing supply in explaining the differences in housing price growth. Regions in the East had the most inelastic housing supply, while northern regions had the most elastic housing supply. Concluding statements are in the final section of the paper.

2. Literature Review

The spatial equilibrium growth model of Glaeser and Tobio (2008) is an extension of the canonical Rosen-Roback spatial equilibrium model (Rosen, 1979, Roback 1982). In the Rosen-Roback model, land is used by both households and firms, and can be transferred between uses without frictions. Perfect mobility of households and firms equalizes utility and profits across space. Therefore, in spatial equilibrium wages and land rents reflect relative location advantages for firms and households. Land rents increase (decrease) in response to higher (lower) household amenity attractiveness and firm productivity.

The spatial equilibrium model has been used extensively to estimate both the regional quality of life and the regional quality of the business environment in countries including China (Zheng et al., 2014b), Germany (Buettner and Ebertz, 2009), Russia (Berger et al., 2008) and the United States (e.g., Roback, 1982; Blomquist et al., 1988; Beeson and Eberts, 1989; Gabriel and Rosenthal, 2004). Assuming that spatial equilibrium holds continuously, the effects of changing household amenity attractiveness and productivity across regions can be examined (Gabriel et al., 2003; Partridge et al., 2010). However, Rickman (2014) notes the passive role of the housing sector in the traditional spatial equilibrium model, where regionally-uniform elasticities of housing supply are assumed and innovations in housing supply are not allowed in spatial equilibrium growth analyses. Considerable evidence exists that housing supply elasticities are not constant across space (Glaeser et al., 2008).

Studies then began to incorporate differing elasticities of housing supply within a spatial equilibrium model. Glaeser et al. (2006) retain the assumption of spatial equalization of utility but do not impose equalization of profits. They then allow the elasticity of housing to vary spatially and demonstrate empirically that labor demand shocks have larger housing price effects in areas with less elastic housing supply and lower population growth. This can explain why in declining U.S. cities there are larger responses in housing prices and lower population outflows (Glaeser and Gyourko, 2005); houses are built more quickly than they depreciate, making housing supply relatively inelastic in declining areas. Krupka and Donaldson (2013) likewise expand the Rosen-Roback model such that household amenity attractiveness and firm productivity do not solely determine wages and rents. Hence, they impose additional equilibrium conditions for the labor and housing markets.

Glaeser and Tobio (2008) take the spatial equilibrium model one step further by incorporating innovations in housing supply. Local areas may enact restrictive housing development policies in response to concerns with adverse effects of growth or may be especially aggressive in promoting growth through expansive housing supply policies. Therefore, the model becomes fairly comprehensive in its ability to account for the various possible sources of growth.

The first use of the model by Glaeser and Tobio (GT) (2008) was to examine the sources of growth in the southern region of the United States over the last half of the twentieth century. A notable finding of the study was that rather than increased demand by households for natural amenities, such as a favorable climate, the most important growth factor in the most recent decades was a more favorable housing regulatory environment in southern states that made housing supply more elastic.

Rickman and Rickman (2011) used the theoretical model of GT to assess the changing role of natural amenity demand in nonmetropolitan county growth for 1990-2000, while accounting for the elasticity of housing supply and labor demand. They found household amenity demand as underlying stronger population growth in areas with higher levels of natural amenities. However, they found amenities becoming fully capitalized in the most amenity attractive areas, which reduced their relative population growth but did not find housing supply to be more inelastic in these areas.

Rickman and Wang (forthcoming) found that both differences in natural amenities and urban agglomeration underpinned U.S. regional growth differences post-2000. However, rather than household amenity demand, it was productivity growth that was stronger in areas with high levels of natural amenities. And rather than urban agglomeration economies, it was increased household amenity attractiveness that underpinned stronger population growth in larger metropolitan areas. In contrast to the 1990s, Rickman and Wang found more inelastic housing supply in the highest natural amenity areas, particularly nonmetropolitan areas.

Davidsson and Rickman (2011) used the framework to examine growth differences in micropolitan areas across the U.S. from 1990-2000. The most important factor was industry composition of the micropolitan areas, in which the GT framework allowed them to detect negative household amenity effects for mining and manufacturing employment shares. The second most important factor was Census Division effects. Using the growth decomposition provided by GT, they assessed the differences across Census Divisions as primarily derived from productivity growth differences, followed by amenity demand, with innovations in household housing supply the least important.

3. Deriving Shocks to Regional Housing Supply

We closely follow the presentations of the spatial equilibrium model by Glaeser and Tobio (2008) and Rickman and Rickman (2011). The model contains two optimizing agents: the household and the firm. The household supplies one unit of labor and is assumed completely mobile across regions. Subject to a budget constraint, the household consumes a composite traded good with a normalized price of unity and housing (H) with price P_h to maximize utility. Amenities (A_h) serve as a utility shifter across regions. Utility of the household is assumed to be represented by the Cobb-Douglas constant-returns-to-scale function, with housing expenditure share α, and is equalized across regions in equilibrium because of perfect household mobility. Equalized indirect utility (V_0) can be written as:

$$V_0 = \alpha^{\alpha}(1-\alpha)^{(1-\alpha)} A_h w P_h^{-\alpha} \quad (1)$$

The firm produces a nationally traded good, with normalized price equal to unity, according to a constant-returns-to-scale Cobb-Douglas function using labor (N), nationally mobile capital (K), and locally fixed capital (Z), with input expenditure shares equal to β, γ, and (1- β-γ), respectively. In addition, site-specific characteristics cause productivity (A_f) to vary regionally. Profit maximization yields the following inverse labor demand function:

$$w = \beta\gamma^{(\gamma/(1-\gamma))} A_f^{1/(1-\gamma)} N^{(\beta+\gamma-1)/(1-\gamma)} Z^{(1-\beta-\gamma)/(1-\gamma)} \quad (2)$$

Equation (2) stands in contrast to the formulation in the canonical Rosen-Roback static spatial equilibrium model. First, land is not used in production of the traded good. So, only households are affected by land prices. Second, profits are not constrained to be equal across regions. As such, spatial differences in productivity do not directly affect land prices, which they do in the traditional spatial equilibrium model. In the traditional spatial equilibrium model, with land transferable between residential and firm uses, the assumptions of equalization of utility and profits across space are sufficient to derive equilibrium wages and rents and the level of population.

The supply of housing is given by the fixed level of land (L) and housing structure (h) on the land. The cost per unit of land is P_l; the cost of housing structure is $\xi_0 h^{\delta}$ where ξ_0 is a constant and δ>1. Free entry and zero economic profits are assumed in the housing sector in equilibrium. Using the first-order profit maximizing level of h, total housing supply is given as:

$h\underline{L}=(ph/\xi_0\delta)^{(1/(\delta-1))}$. Equating housing demand with housing supply in equilibrium yields the following equilibrium expression for housing prices:

$$ph=((N/\underline{L})\alpha w)^{((\delta-1)/\delta)}\delta^{(1/\delta)}\xi_0^{(1/\delta)} \quad (3)$$

The housing market equilibrium condition is required because of the absence of land as an input into production and the absence of a firm profit constraint.

In natural logarithms, the static equilibrium conditions for population (assuming full employment), wages and housing prices from the above are as follows (Glaeser and Tobio, 2008; Rickman and Rickman, 2011):

$$\ln(N) = K_N + (\delta + \alpha - \alpha\delta)\ln(\boldsymbol{A}_f) + (1-\gamma)(\delta\ln(\boldsymbol{A}_h) + \alpha(\delta-1)\ln(L))/\Delta \quad (4)$$

$$\ln(w) = K_w + (\delta-1)\alpha\ln(\boldsymbol{A}_f) + (1-\beta-\gamma)(\delta\ln(\boldsymbol{A}_h) + \alpha(\delta-1)\ln(L))/\Delta \quad (5)$$

$$\ln(P_h) = K_H + (\delta-1)\ln(\boldsymbol{A}_f) + \beta\ln(\boldsymbol{A}_h) - (1-\beta-\gamma)\ln(L))/\Delta \quad (6)$$

where K_N, K_w and K_H are constant terms derived from the solutions and $\Delta = \delta(1-\beta-\gamma) + \alpha\beta(\delta-1)$.

Equations (4)-(6) can be used to assess the influence of housing supply elasticity on regional outcomes by estimating regressions for the three variables, and include measures of shocks that are interacted with proxies for housing supply elasticity (Glaeser et al., 2006). Labor demand shocks will increase housing prices more relative to population in areas with less elastic housing supply. Other sources of growth can come from increased household amenity attractiveness through life cycle factors and increased national income (Graves, 1979; Gyourko et al., 2013).

To derive corresponding growth equations, unanticipated exogenous shocks to amenity demand, firm productivity and housing supply elasticity are added to equations (4) to (6) (Rickman and Rickman, 2011). Assuming that the static equilibrium conditions hold between periods t and t+1, equations (4) to (6) can be transformed into growth equations:

$$\ln(N_{t+1}/N_t) = £_N + \Delta^{-1}\left((\delta + \alpha - \alpha\delta)\lambda_f + (1-\gamma)(\delta\lambda_h + \alpha(\delta-1)\lambda_L)\right)\boldsymbol{R} + \varepsilon_N \quad (7)$$

$$\ln(w_{t+1}/w_t) = £_W + \Delta^{-1}\left((\delta-1)\alpha\lambda_f - (1-\beta-\gamma)(\delta\lambda_h + \alpha(\delta-1)\lambda_L)\right)\boldsymbol{R} + \varepsilon_W \quad (8)$$

$$\ln\left(P_{h,t+1}/P_{h,t}\right) = £_H + \Delta^{-1}\left((\delta-1)(\lambda_f + \beta\lambda_h - (1-\beta-\gamma)\lambda_L\right)\boldsymbol{R} + \varepsilon_H \quad (9)$$

where λ_f, λ_h and λ_L are the shocks to firm productivity, household amenity attractiveness and land supply common within regional category $\boldsymbol{R}$. The £ represent shocks common to all regions, while the ε represent shocks idiosyncratic to areas.

Let $\boldsymbol{B_{N,}} \boldsymbol{B_W}$ and $\boldsymbol{B_H}$ represent the expressions multiplied by $\boldsymbol{R}$ in Equations (7) to (9), respectively. The expressions associated with them can then be solved simultaneously to obtain the innovations in productivity, amenity attractiveness and land supply. We focus on deriving the innovations to land supply.[1] Various policies are available and have been used to affect regional housing supply in China (Ye et al., 2011; He, 2013; Wu, 2015).

Relative growth in land supply (λ_L) is obtained as

$$\mathbf{B_N} + \mathbf{B_W} - (\delta\mathbf{B_H}/(\delta-1)) \quad (10)$$

[1] Derivations of shocks to firm productivity and household amenity attractiveness can be found in Glaeser and Tobio (2008) and Rickman and Rickman (2011).

Strong population and wage growth relative to housing price growth is evidence of greater elasticity of land supply. Less elastic supply of land restricts population growth and increases housing prices relative to wages.

To estimate the impacts of the housing price shocks on housing prices we derive the multiplier effects of the shocks in Equation (9). A one percent change of land supply causes a

$-(\delta - 1)(1 - \beta - \gamma)\, \Delta^{-1}$ percent change in housing prices. (11)

4. Empirical Implementation

4.1 Data

According to the Constitution of the People's Republic of China, China's administrative units are currently based on a three-tier system.[2] The first tier includes provinces, autonomous regions and municipalities directly under the Central Government; the second tier includes autonomous prefectures, autonomous counties and cities that would compose provinces and autonomous regions; the third tier includes townships, ethnic minority townships, and towns that would compose counties, autonomous counties and cities. In this paper, the analysis will focus on the first tier that includes 23 provinces, 5 autonomous regions and 4 municipalities directly under control of the Central Government.[3] Table 1 presents the areas of study, including their classification and region of location in mainland China.

The regional data we utilize in this paper are all publicly available. Data are obtained from the National Bureau of Statistics of the People's Republic of China for population, wage

[2] The Central People's Government of the People's Republic of China website link is http://english.gov.cn/.
[3] This paper focuses only on mainland China. Thus, the two special administrative regions Hong Kong and Macao are excluded.

and salary income per capita, and the average regional housing price.[4] We calculate the average annual growth rates for the variables over the period of 1999-2013.

According to China Statistical Yearbooks, population in 1999 and 2013 were estimated on the sample surveys on population changes that cover about one per thousand of the total population of the country. The military personnel were not included in the regional population.

Housing price refers to average selling price per square meter of commercialized residential buildings that are built by real estate companies and traded in the housing market. Data are obtained from the National Bureau of Statistics of the People's Republic of China. Regarding wage and salary income per capita, we can only obtain data for urban and rural areas separately. Thus, we use the urbanization ratio, calculated as urban population divided by total population, to weight the urban and rural per capita incomes.[5] For Tibet because of missing data in 1999 we calculate the average annual growth rate from 2000-2013.

4.2 Growth during the Post-Market Reform Era

Annual compounded growth rates for housing prices, per capita income and population by area of study for the post-market reform period of 1999 to 2013 appear in Table 2. As shown in the first column of Table 2, housing prices increased the most in the East. The four municipalities under the control of the Central Government experienced the next fastest growth. Note that Shanghai is classified as both in the East and as a municipality. The Northeast provinces experienced the slowest growth in housing prices. Strongest growth in per capita income occurred in the Central areas, followed closely by those in the East and Northwest. Municipalities experienced the slowest growth in per capita income. Yet, municipalities also had

[4] National Bureau of Statistics of the People's Republic of China website link is http://www.stats.gov.cn/english/.
[5] The online database for rural and urban population is only available since 2005 and afterwards. Therefore, we calculated the 2013 urbanization ratio using rural and urban population. For 1999, we adopted the ratio from http://www.doczj.com/doc/886469aad0d233d4b04e6916.html.

the fastest growth in population. Slowest growth in population occurred in the Northeast and Southwest.

4.3 Empirical Model

Equations (7) to (9) are implemented as natural log-differences in population, wages and housing costs between years t and t+1:

$$\ln(pop_{t+1}/pop_t) = £_N + \boldsymbol{B_N R} + \varepsilon_N \qquad (12)$$

$$\ln(wage_{t+1}/wage_t) = £_W + \boldsymbol{B_W R} + \varepsilon_W \qquad (13)$$

$$\ln(hous_{t+1}/hous_t) = £_H + \boldsymbol{B_H R} + \varepsilon_H \qquad (14)$$

where $£_N$, $£_W$ and $£_H$ are constants. $\boldsymbol{B_N}$, $\boldsymbol{B_W}$ and $\boldsymbol{B_H}$ are the coefficient vectors for the binary indicator variables to be estimated. ε_N, ε_W and ε_H are error terms. **R** is the matrix of variables of interest to assess housing supply elasticity across mainland China. Included is a vector of binary indicator variables representing the geographic region of the province/municipality, and binary indicator variables for whether the area is a municipality under direct control of the central government and whether a province is autonomous.

For Glaeser and Tobio (2008), in the base regressions **R** represented whether a U.S. metropolitan area was located in one of the eleven former confederate states. In Rickman and Rickman (2011), **R** corresponded to a vector of binary variables for the amenity ranking of U.S. counties produced by Economic Research Service (ERS) of the United States Department of Agriculture. In Rickman and Wang (forthcoming), **R** represented both binary variables for natural amenity attractiveness and binary variables for the area's position along the rural-urban continuum based on the classification by ERS. This allowed for testing the relative importance of natural amenities versus urban agglomeration in the growth differences across the United States.[6]

[6] In addition to representing binary indicator variables as in the other studies, in Davidsson and Rickman (2011) **R** also represented time varying variables. Such variables included: measures of natural amenities; location in the U.S.

5. Results

5.1 Regression Results

The results from estimating Equations (12)-(14) with ordinary least squares are shown in Table 3. The reported t-statistics reflect heteroscedasticity-consistent standard errors. The Central region of China is the omitted category, with its growth reflected in the constant terms.

As shown in the first column of Table 3, the differences in housing price growth across regions of China are statistically significant below the 0.10 based on an F-test. Areas in the East experienced over two percent greater annual compounded growth in housing prices than those in the Central region. Provinces in the Northeast experienced nearly two percent less annual compounded growth. Autonomous provinces as a group, and municipalities as a group, did not experience significantly different growth in housing prices.

The second column of Table 3 shows that collectively the other areas did not experience statistically different growth in per capita income. Yet, provinces in the Northeast and municipalities experienced nearly two and one-half percent slower per capita income growth. Re-estimating the per capita income growth equation after removing all variables other than the indictor variables for the Northeast and municipal areas produced a statistically significant regression (p=0.056), with each coefficient approximately equal to negative two (not shown). This confirms the results for these two regions relative to Central provinces shown in the table.

Regression results for population growth are shown in the third column of Table 3. Population growth exhibits the strongest regional pattern, as evidenced by the highest r-squared and largest F-statistic. But only municipalities had statistically different growth than Central

rural-urban hierarchy; industry composition; and state and local tax and expenditure variables. Binary variables included Census Division, location of a land grant university, and right-to-work status.

provinces, where municipalities on average experienced over two percent greater growth per year.

5.1 Housing Price Decomposition Results

The coefficients from Table 3 are $\boldsymbol{B_N}, \boldsymbol{B_W}$ and $\boldsymbol{B_H}$ in Equation (10), which produces the estimates of $\boldsymbol{\lambda_L}$. The values for $\boldsymbol{\lambda_L}$ can then be used with Equation (11) to estimate the elasticity of housing supply effects on housing prices. Equations (10) and (11) require parameters for the model. For the base case, the following values from Glaeser and Tobio (2008) are specified for the model parameters: β=0.3, γ=0.6, α=0.3 and δ alternatively is set equal to 1.5 and 3.0. In sensitivity analysis, parameters likely to be more accurate for China are set as β=0.6, γ=0.3, α=0.5.

The first two columns of Table 4 show the differences in housing supply innovations ($\boldsymbol{\lambda_L}$) relative to the omitted category, Central China, for δ=1.5 and δ=3.0, respectively. A value of 1.5 implies an elasticity of price with respect to density of 0.5, while a value of 3.0 implies an elasticity of 3 (Glaeser and Tobio, 2008). In column (1), the Northeast provinces are estimated to have had the most positive housing supply innovations, followed next by the Northwest. The most negative housing supply innovations are estimated to have occurred in the East, followed by Municipalities and the Southwest. As shown in column (2), specifying a larger elasticity of price to density instead predicts the Northwest and the North to have had the most elastic housing supply. The most negative housing supply continues to be the East, followed next by the Southwest and then Municipalities. Overall, the results are not much affected by varying the elasticity of price to density; primarily it is the ordering among the top four most elastic regions that is affected.

Negative housing supply innovations can feed speculative price bubbles (Rickman and Guettabi, 2015). Thus, the most negative housing supply effects in the East is consistent with the evidence reported by Wang and Zhang (2014) that housing prices were higher in several coastal cities than suggested by fundamentals such as income and population. Yu (2011) similarly reports significant housing price bubbles since 2005 in the eastern cities of Beijing, Shanghai, Shenzhen, Hangzhou and Ningbo.

The third and fifth columns reflect the results of using the estimated innovations with Equation (11) to predict the relative change in housing prices from the differences in housing supply innovations. Positive (negative) predicted housing price increases in columns (3) and (5) reflect negative (positive) housing supply innovations in columns (1) and (2), respectively. The fourth and sixth columns are the ratios of the predicted housing price changes in columns (3) and (5) to the actual relative changes in housing prices given in column (1) of Table 3. The multipliers are the same across regions, so the pattern of differences in predicted effects reflect that of the differences in innovations in the first two columns.

From the fourth column, regions with the largest positive innovations in the first column, the Northeast and Northwest, had thirty-seven percent and eighty-two percent of their relative changes in housing prices explained by relative housing supply innovations, respectively. The East, the region with the most negative housing supply innovations in the first column, had seventy-five percent of its relative increase in housing prices explained by its relative negative housing supply innovations. Thus, for the East and Northwest regions most of their relative changes in housing prices are attributable to differential innovations in housing supply, not fundamental demand factors related to the attractiveness of the regions to firms and households.

For the large Municipal regions relative negative innovations in housing supply can explain nearly all of the actual relative change in housing prices.

The Southwest, North and Autonomous regions had predicted changes in excess of the actual changes. Thus, fundamental forces worked to dampen or offset the relative effects on housing prices from housing supply innovations. For the North provinces, housing prices would have been lower had it not been for stronger relative fundamental demand forces. For the Southwest and Autonomous provinces, negative effects from fundamental demand factors on housing prices were in the opposite direction of the increased prices from negative relative housing supply innovations. In fact, the negative sign for Autonomous provinces indicate the actual relative prices were negative, despite housing supply predicting there to be relative positive price increases.

The results in the sixth column, reflecting δ=3.0, are qualitatively similar to those in the fourth column. The only switch in signs occurs for the Northeast provinces, in going from a small positive number to barely negative. This suggests that for this region, the significantly lower growth in housing prices (from column (1) of Table 3) results almost exclusively from relatively lower fundamental demand.

In sensitivity analysis, Table 5 shows alternative results to those in columns (3)-(6) in Table 4. The results are obtained by specifying different factor production shares and household expenditure share on housing: α=0.5 and β=0.6, γ=0.3. These reflect greater labor intensity in production and a larger expenditure share on housing. Estimated housing supply innovations are not affected by these changes (Equation (10)), so the first two columns of Table 4 do not change and are not reproduced in Table 5.

As shown in Table 5, the pattern of results across the regions holds when assuming the alternative values of the model parameters. The signs do not switch because they are determined by the estimated innovations. Thus, all the magnitudes are affected proportionately because only the multipliers change. The predicted effects on relative housing prices are about 0.65 of the Table 4 predicted effects for δ=1.5 and 0.53 of the predicted effects for δ=3.0. Overall, the estimated roles of relative innovations in housing supply are still quantitatively significant for most regions. A notable change, for example, is that only about one-half, rather than the approximately ninety percent in Table 4, of the change in relative housing prices in municipal regions is now estimated to have occurred because of relatively negative innovations in housing supply.

6. Conclusion

In this study we apply a spatial equilibrium growth model to provinces and municipalities of mainland China from 1999-2013 to assess the role of differences in housing supply in regional differences in housing price growth. Innumerable factors can underlie differences in economic fundamentals and housing supply across regions, and the general structure of the spatial equilibrium framework can account for them (Ottaviano and Pinelli, 2006; Tabuchi and Thisse, 2006). For example, the relaxing of *hukou* restrictions would increase household demand for cities with higher amenities, increasing their population growth and housing prices; Zheng et al. (2014a) find lower pollution to be more fully capitalized into housing prices in cities with less restrictive *hukou* regulations on labor mobility. Promotion of housing supply such as through relaxing housing regulations or public provision of housing (Cao and Keivani, 2014) would increase population growth relative to the change in housing prices.

We first find that there were significant geographical differences in housing price growth across mainland China during the post-market reform era. We find that relative differences in housing supply played major, if not dominant roles, in the differences in housing price growth. This is a result that is robust to alternative parameterizations of the spatial equilibrium model. While the factors potentially underlying the housing supply differences are numerous and difficult to fully identify, the results from the spatial equilibrium growth model highlight the important role of housing supply in determining regional housing prices in mainland China.

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Table 1. Units of Observation

Province/Municipality	Region	Municipality	Autonomous
Beijing	North	Yes	No
Tianjin	North	Yes	No
Hebei	North	No	No
Shanxi	North	No	No
Inner Mongolia	North	No	Yes
Liaoning	Northeast	No	No
Jilin	Northeast	No	No
Heilongjiang	Northeast	No	No
Shanghai	East	Yes	No
Jiangsu	East	No	No
Zhejiang	East	No	No
Anhui	East	No	No
Fujian	East	No	No
Jiangxi	East	No	No
Shandong	East	No	No
Henan	Central	No	No
Hubei	Central	No	No
Hunan	Central	No	No
Guangdong	Central	No	No
Guangxi	Central	No	Yes
Hainan	Central	No	No
Chongqing	Southwest	Yes	No
Sichuan (excluding Chongqing)	Southwest	No	No
Guizhou	Southwest	No	No
Yunnan	Southwest	No	No
Tibet	Southwest	No	Yes
Shaanxi	Northwest	No	No
Gansu	Northwest	No	No
Qinghai	Northwest	No	No
Ningxia	Northwest	No	Yes
Xinjiang	Northwest	No	Yes

Table 2. Annual Compounded Growth: 1999-2013

Region Classification	Housing Prices %Δ '99-'13 (annual)	Per Capita Income %Δ '99-'13 (annual)	Population %Δ '99-'13 (annual)
Central	10.90	16.65	0.71
East	13.29	16.47	1.17
North	10.97	16.16	1.93
Northeast	9.12	14.43	0.25
Northwest	10.16	16.34	0.94
Southwest	11.21	15.57	0.26
Autonomous	10.54	15.53	1.06
Municipality	12.04	14.54	2.76

Table 3. Regression Results (robust t-statistics in parentheses)

Region Classification	Housing Prices	Income	Population
Constant (Central)	10.91 (14.83)*	16.87 (15.99)*	0.63 (1.10)
East	2.29 (2.18)**	-0.05 (-0.05)	0.24 (0.37)
North	-0.15 (-0.18)	0.54 (0.40)	0.35 (0.49)
Northeast	-1.80 (-2.08)**	-2.44 (-1.85)***	-0.38 (-0.66)
Northwest	-0.72 (-0.64)	0.01 (0.01)	0.12 (0.19)
Southwest	0.20 (0.15)	-0.54 (-0.36)	-0.89 (-1.13)
Autonomous	-0.10 (-0.11)	-1.35 (-0.90)	0.50 (0.87)
Municipality	0.57 (0.84)	-2.45 (-3.12)*	2.12 (2.59)**
R-Squared	0.42	0.26	0.50
F-Statistic	2.42 (p=0.052)	1.18 (p=0.35)	3.26 (p=0.015)

*significant at or below the 0.01 level; **significant at or below the 0.05 level; ***significant at or below the 0.01 level

Table 4. Relative Housing Supply Innovations and Effects on Housing Prices: Base Case

Region	Innovation (δ=1.5)	Innovation (δ=3.0)	Housing Price (δ=1.5)	Predicted/ Actual	Housing Price (δ=3.0)	Predicted/ Actual
East	-6.68	-3.25	1.71	0.75	1.35	0.59
North	1.34	1.12	-0.34	2.30	-0.47	3.11
Northeast	2.60	-0.11	-0.67	0.37	0.05	-0.03
Northwest	2.28	1.20	-0.58	0.82	-0.50	0.70
Southwest	-2.02	-1.73	0.52	2.65	0.72	3.68
Autonomous	-0.55	-0.70	0.14	-1.38	0.29	-2.87
Municipality	-2.05	-1.19	0.53	0.92	0.50	0.87

Table 5. Sensitivity Analysis: Predicted Effects on Housing Prices

Region	Housing Price (δ=1.5)	Predicted/ Actual	Housing Price (δ=3.0)	Predicted/ Actual
East	1.12	0.49	0.72	0.32
North	-0.22	1.50	-0.25	1.66
Northeast	-0.43	0.24	0.02	-0.01
Northwest	-0.38	0.53	-0.27	0.37
Southwest	0.34	1.73	0.38	1.96
Autonomous	0.09	-0.90	0.16	-1.53
Municipality	0.34	0.60	0.27	0.46