# The Estimation and Determinants of the Price Elasticity of Housing Supply: Evidence from China

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Abstract

This paper provides a first look at estimates of the price elasticity of the housing supply in China at both the national and city levels. Using a panel dataset consisting of 35 cities in China from 1998 to 2009, the findings show that the implied national price elasticity of housing supply is between 2.8 and 5.6. The city-level analysis reveals that geographic, economic as well as regulatory factors are significant determinants of the variation in the observed price elasticity of housing supply. The study of a different regulatory and economic environment contributes to the growing literature on supply elasticity and helps explain the seemingly wide variation in supply elasticities observed across cities and countries.

The rapid growth in housing prices in many cities around the world since the late 1990s has motivated a growing number of studies (Jud and Winkler, 2002; Glaeser, Gyourko, and Saiz, 2008; Goodman and Thibodeau, 2008; Wheaton and Nechayev, 2008; and Shi, Young, and Hargreaves, 2010) to examine the variation in housing price dynamics across cities or regions. Although strong economic growth and intensified housing financial support along with other demand-side factors may have played a role in the recent run-up in housing prices, these demand-side factors alone are insufficient to capture the variations in the regional price dynamics. Hence, an increasing number of supply-side studies have started to surface to shed light on the role housing supply plays in housing price dynamics.

One focus of such housing supply studies is on estimating the price elasticity of housing supply, a parameter that measures the responsiveness of housing supply to a change in housing price. This parameter is important for housing market and policy analyses as it has implications to the relation between house price fluctuations and demand shocks. The magnitude of housing price changes as well as the time taken to restore a new level of price equilibrium due to an unexpected shock in housing demand are greatly affected by the price elasticity of housing supply. Prior studies used different models to analyze data at the national or city level over selected time periods, finding a wide range of empirical estimates of this supply parameter. However, there is yet to be a consensus on the method to estimate the price elasticity of housing supply. In addition, the bulk of the evidence focuses on the housing market in the United States, with only limited evidence on non-U.S. markets.

In general, the literature on supply elasticity addresses two related research questions. The first concerns the extent to which supply elasticity impacts housing price dynamics. Prior studies on this issue (Wheaton, 2005; Glaeser, Gyourko, and Saks, 2008; and Grimes and Aitken, 2010) generally confirm an inverse relationship, that is, a more elastically supplied housing market tends to have lower price levels as well as smaller price volatilities than a market with less elastic supply. The second question concerns the sources of variation in the estimated price elasticity of housing supply across different countries (Mayo and Sheppard, 1996; Malpezzi and Mayo, 1997; Malpezzi and Maclennan, 2001; and Vermeulen and Rouwendal, 2007) or different cities/regions within a country (Harter-Dreiman, 2004; and Green, Malpezzi, and Mayo, 2005). However, while some of the papers include one or two factors (regulatory, economic, and geographic) in their analyses, none of them analyzed all the three factors simultaneously.

The aim of this study is twofold. First, it seeks to estimate an aggregate or nation-wide price elasticity of the housing supply in China to throw light on the comparative responsiveness of the housing supply in China relative to other countries. Second, it seeks to estimate the price elasticity of the housing supply at the city-level as well as identify the key determinants of variations in housing supply responsiveness across cities/regions in China. An examination of the regulatory, economic, and geographic related factors may help shed light on the relative importance of the factors in explaining differences in housing supply elasticity.

China, similar to the U.S., exhibits significant local variation in land availability, population density, infrastructure, and regulatory practices. However, it is an emerging economy with a recently liberalized private housing market. Its supply environment is unique in that all urban land in China is collectively owned by the people through the National People’s Congress of the People’s Republic of China. The central as well as the local governments in China exert a strong influence on the development process through the timing of land supply [see Lai and Wang (1999) and Chan, Fang, and Yang (2011) for a discussion of land supply policies on developers’ housing supply strategies]. In addition, the prevalent use of a presale system in China to sell development projects is a unique feature influencing the supply decisions of developers [see Lai, Wang, and Zhou (2004), Chan, Fang, and Yang (2008, 2012), and Fang, Wang, and Yang (2012) for a discussion of this issue]. Given the above unique features of China, the current study certainly adds a new dimension to the international comparative literature on housing supply elasticity as well as provides additional insights into the underlying forces shaping the heterogeneous housing supply responsiveness across cities or regional markets. The latter results may have implications to the differential house price sensitivities to demand shocks observed across cities.

This study examines the 35 largest cities in China (most of which are provincial capital cities) over a 12-year period from 1998 to 2009. Using a modified version of Malpezzi and Maclennan's (2001) stock adjustment model to estimate the aggregate price elasticity of supply, we find that the estimated elasticity for China falls in the range of 2.82 to 5.64. Relative to other countries, this estimate puts China in a moderately elastic supply category together with postwar U.S. and prewar U.K. The estimate for China is lower than that for countries with liberal regulatory environments (such as prewar U.S. and Thailand) but higher than that for countries with stringent regulatory environments (such as postwar U.K., the Netherlands, Korea, and Malaysia). The finding adds to existing evidence that seems to indicate that the price elasticity of supply is correlated with the stringency of the regulatory environment.

Further, we directly estimate the price elasticity of the housing supply at the city level [as in Green, Malpezzi, and Mayo (2005) and Grimes and Aitken (2010)] and explore the sources of variation in those estimates across the 35 cities in China, finding the key determinants to be the availability of developable land, the average urban built-up area, the growth rate of population, and the regulatory restrictions on land use and/or land supply. Of those determinants, geographical constraint affecting the availability of developable land seems to be the most important. Overall, the findings help enrich our understanding of China's housing market from the supply side and fill a gap in the literature on China's housing market that, in general, has largely overlooked housing supply elasticity as an explanatory variable in housing price dynamics.

The remainder of the paper is organized as follows. The next section provides a brief overview of China's evolving housing market, followed by a review of the related literature in section three. Section four discusses the estimation model, the data, and the estimates for the national price elasticity of housing supply. Section five estimates city-level housing supply elasticities, identifies their determinants, and discusses the results, while the final section concludes.

## A Brief Overview of China's Housing Market

The replacement of the welfare housing system in China in 1998 with one that is market-oriented has led to a gradual release of pent-up demand for private housing. Over the decade from 1998 to 2009, the number of new immigrants to the major cities in China grew substantially and the rate of urbanization increased from 30% to about 47%. Under such demand shifts and a booming economy, many of the urban housing markets across China experienced a sustained price increase. The average price appreciation rates over this period were 36%, 24%, and 20% in the East, West, and Central regions, respectively.[1] It is noteworthy that throughout the period, housing price levels in the East were substantially higher than the national average and the levels in the West and Central regions.

Such price appreciations occurred despite the fact that, in mid-2003, the central government of China began to launch a wide range of regulatory policies (including mortgage and reserve rates adjustments, tax rate adjustments, housing price regulation, land-use rights transaction reform and supply structure regulation) to restrain the rising residential prices (see Wang and Yang, 2010).[2] The supply-side policy measures, in particular, are aimed at improving housing supply responsiveness to demand shocks as well as providing more affordable housing for low and medium income households. Given that demand-side regulations were found to have rather limited effects in curbing house price appreciations, increasing attention has shifted to supply-side policies in the later years.

While price appreciation rates differ across regions, new housing supply also exhibits distinctive trends across regions during the 1998 to 2009 period (Exhibit 1). Of note is the general increase in housing starts across all regions over the period, with the level of housing starts in the East consistently higher than the Central and West regions up until around 2004, after which the levels in the East fell below that of the Central region and began to approach that of the West. Recognizing that variations in housing supply would likely be larger across cities than across regions, our prior is that such variations are possibly correlated with the regulatory, economic and geographic features unique to each region/city.

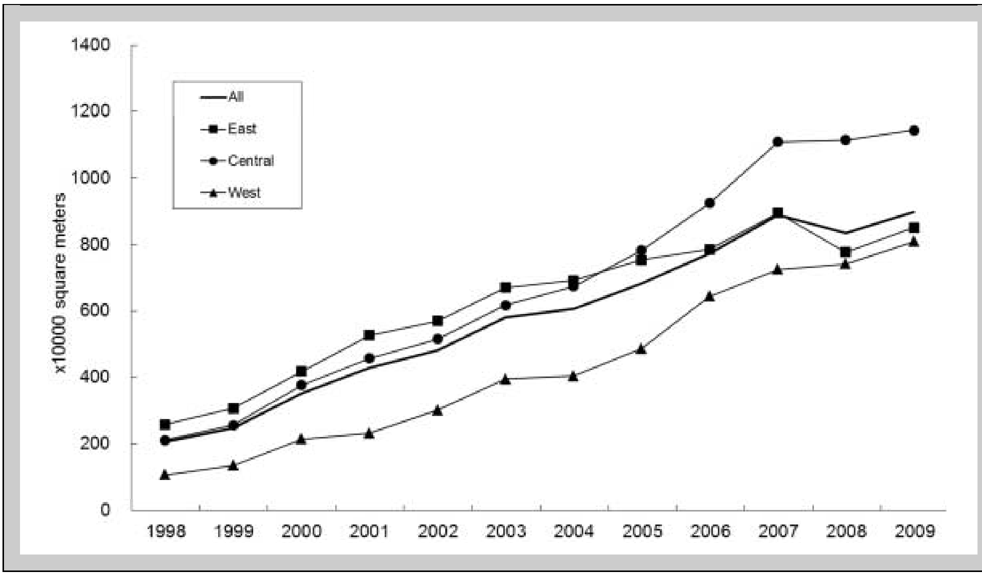
## Prior Research on Housing Supply Elasticity

There is a growing literature on housing supply elasticity focusing mainly on the U.S. housing market with only a handful of studies examining non-U.S. housing markets. These studies, however, vary in their estimation methods and produce a wide range of supply elasticities (Kim, Phang, and Wachter, 2012). To date, although there is a fair degree of agreement on the fundamental factors affecting housing supply, there is yet to be a consensus as to which estimation method of the price elasticity of supply is best. The reason could be related to problems with data availability and aggregation bias in the data (DiPasquale, 1999; and Harter-Dreiman, 2004). This section reviews the estimation methods used in the literature and the results obtained.

### *Estimation Methods*

Prior studies use one of three main types of models, each involving different econometric techniques, to estimate the price elasticity of housing supply (a numerical measure of the responsiveness of the housing supply to a change in housing price). The first type is based on the Tobin's *q* theory, which posits that the level of housing investment is a positive function of the ratio of housing prices to construction costs. Studies using this approach include Muth (1960), Follain (1979), Green, Malpezzi, and Mayo (2005), Vermeulen and Rouwendal (2007), and Grimes and Aitken (2010). Most of empirical settings in the above studies are reduced form equations with price and cost shifters (typically, land cost, material cost, labor cost, and various interest costs) on the right-hand side.

**Exhibit 1** | New Housing Starts in China and by Region (1998–2009)




*Notes:* The data source is the National Bureau of Statistics. New housing start level is measured as the newly started floor area of residential housing. Regional housing start is a numerical average of the housing starts (in square meters) in cities in a region.

The second type of model is based on the stock-flow adjustment theory whereby a stock adjustment process equilibrates housing supply and demand.[3] New housing supply is added to meet increasing housing demand and to fill the gap resulting from potential demolishment of properties in the housing stock. However, the current housing stock adjusts to the long-run desired level at a certain speed (which may not necessarily clear the market within one year). Topel and Rosen (1988) and Blackley (1999) were the first to incorporate the stock adjustment process into their theoretical and empirical research.[4] Malpezzi and Mayo (1997) and Malpezzi and Maclennan (2001) propose models to indirectly estimate housing supply elasticity in a flow or stock-adjustment setting using several parameters: the income elasticity of housing demand, the price elasticity of housing demand, and the income elasticity of housing price. Both the original and modified versions of these models have been widely used in international comparative studies (Mayo and Sheppard, 1996; Harter-Dreiman, 2004; Goodman, 2005; and Goodman and Thibodeau, 2008). The model used in this strand of literature is also reduced form in nature in which one period lagged housing stock appears on the right-hand side as an independent variable.

The third type is a structural model based mainly on urban spatial theory and explicitly accounts for land as an input of housing construction (DiPasquale and Wheaton, 1994; Peng and Wheaton, 1994; and Mayer and Somerville, 1996, 2000a, 2000b). Poterba (1984) and Saiz (2010) are two other studies that incorporate land into their housing supply estimation.

In the above studies, housing starts (or changes in the stock of housing, net of removals), new residential constructions or housing permit issuances are generally used as a measure of new housing supply (a flow variable). However, in the model to estimate the price elasticity of housing supply, some studies specify the variables in levels (e.g., Topel and Rosen, 1988; Malpezzi and Maclennan, 2001; and Grimes and Aitken, 2010) while others specify the variables in differences (e.g., Mayer and Somerville, 2000b; and Goodman and Thibodeau, 2008).

Mayer and Somerville (2000b) argue that, since housing price is a stock variable while new housing supply is a flow variable, it is proper to use price change (a flow variable) to explain the dynamics of housing supply. (Note that this argument focuses on the time-series properties of the data to avoid spurious regression.) Grimes and Aitken (2010), however, justify the use of a price levels modeling approach by pointing out that the existence of a co-integration relationship between housing supply and its explanatory variables should be the key consideration rather than how the variables are specified. Hence, it is necessary to perform a co-integration test on the variables to check the appropriateness of their specification in the model.

## *Empirical Estimates of the Price Elasticity of Housing Supply*

With different models, econometric techniques, data (national or MSA level), and time periods used, prior studies generate a wide range of estimates for the price elasticity of housing supply. At the national level, Muth (1960), using a reduced form model, finds that the U.S. has highly elastic housing supply between the First and the Second World Wars. Follain (1979), using data from 1947 to 1975, obtains a similar estimation of high elasticity for the U.S. However, Poterba (1984), using a structural asset-market model data from 1963 to 1982, obtains an estimate between 0.5 and 2.9. Topel and Rosen (1988) find a short-run (one-quarter) and longer-run supply elasticity of 1.0 and 3.0, respectively, but note that most of the difference vanishes within one year. DiPasquale and Wheaton (1994), using an urban spatial model and U.S. data from 1963 to 1990, find an elasticity estimate ranging from 1.0 to 1.2 for new housing construction and 1.2 to 1.4 for housing stock, while Blackley (1999), using 1950 to 1994 U.S. data, obtains estimates ranging from 1.6 to 3.7 for new residential constructions. Malpezzi and Maclennan (2001) obtain estimates ranging from 4 to 10 (prewar) and 6 to 13 (postwar) using a flow model and estimates ranging from 1 to 6 (postwar) using a stock adjustment model.

More recently, Harter-Dreiman (2004) uses a VEC model to estimate housing supply elasticities for 76 MSAs in the U.S. and finds the range to be from 1.8 to 3.2. Green, Malpezzi, and Mayo (2005) also find a wide distribution of supply elasticity estimates for 45 U.S. cities, with the city-level estimates ranging from −0.30 to 29.9. Goodman (2005), using data on 317 U.S. suburban areas in the 1970s, 1980s, and 1990s, obtains supply elasticity estimates in the range of 1.26 to 1.42 while Goodman and Thibodeau (2008), examining 133 U.S. MSAs from 1990 to 2000, find the range to be from −1.37 to 2.98. Saiz (2010), using topographically-derived estimates of developable land ratio along with the local regulation data from the literature, obtains housing supply elasticity estimates in the range of 0.6 to 5.45 for 95 U.S. MSAs.

In addition, several studies estimate the housing supply elasticity for countries outside the U.S. For the U.K., Malpezzi and Maclennan (2001) find the elasticity estimate based on a flow model to be between 1 and 4 (prewar) and between 0 and 1 (postwar) and the estimate based on a stock adjustment model to be between 0 and 0.5 (postwar). Mayo and Sheppard (1996) find Malaysia's supply elasticity to be between 0 and 1.5, Korea's to be between 1 and 1.5, and Thailand's to be near infinite. In another study, Malpezzi and Mayo (1997) find Malaysia's supply elasticity to be between 0 and 0.35, Korea's to be between 0 and 0.17, and Thailand's to be near infinite. Peng and Wheaton (1994) find the supply elasticity to be 1.1 in Hong Kong while Vermeulen and Rouwendal (2007) find zero elasticity in the Netherlands, both in the short run and the long run.

In summary, the above studies offer a wide range of estimates on housing supply elasticity across different countries and even for the same country. This variation may be attributed partially to differences in methodologies employed and partially to differences in regulatory, economic, and/or geographic features unique to each country or city.

## *Sources of Variation*

A large number of the studies exploring the sources of differences in housing supply elasticities across countries or cities focus on the relative stringency of regulatory policies on land and housing development in those countries or cities. These studies use a variety of regulation indices [such as that from Gyourko, Saiz, and Summers (2008)], the number of governing bodies, the number of regulation policies, months to receive subdivision approval, the number of growth management policies instituted by a local authority or a development fee (Manning, 1996; Mayer and Somerville, 2000a; Green, Malpezzi, and Mayo, 2005; and Quigley and Raphael, 2005). Generally, these studies find a statistically significant negative effect of regulatory stringency on housing supply elasticity. In addition, Green, Malpezzi, and Mayo (2005) find that factors such as population density, population levels, population change, and house price levels are also important in influencing regional/city-level housing supply elasticity.

To date, Saiz (2010) is the only study in the literature that uses satellite-generated data on terrain elevation and the presence of water bodies to testify that physical land constraint (in addition to regulatory constraint) is important in explaining housing supply elasticity. Saiz proposes a model that links geography with housing supply directly through constraints on land availability and indirectly through regulatory constraints, the latter of which are endogenous to prices and past growth. His main finding is that the amount of undevelopable land in U.S. metropolitan areas is a key factor impacting housing supply elasticity in the areas examined.

From these studies, it is evident that regulatory, economic, and geographic factors affect the supply elasticity of housing. To date, however, no research has examined the impact of all the three groups of factors simultaneously on housing supply elasticity. This paper fills this gap and examines the influence of these three factors, as well as their relative importance, in determining the price elasticities of housing supply across China's urban cities.

## Aggregate Estimate of the Price Elasticity of Housing Supply in China

### *The Model and Empirical Specifications*

The model for estimating the price elasticity of housing supply at the aggregated level builds upon the simple stock adjustment model presented by Malpezzi and Maclennan (2001). However, the accuracy of the estimates of supply elasticity also hinges on the specification of the reduced-form house price equation and estimates of the demand elasticities (Meen, 2005; and Kim, Phang, and Wachter, 2012). To address this issue, we embellish the Malpezzi and Maclennan (2001) model to include a real cost of homeownership variable in the demand equation to capture its influence on housing demand, two period lagged housing prices in the supply equation to examine the possibility of lags in the housing supply adjustment given a lengthy housing construction process, and construction cost and capital cost in the housing supply equation given that both are important indicators influencing the housing supply decision.[5]

The embellished version of Malpezzi and Maclennan's (2001) stock adjustment model is as follows:

$$\begin{aligned}
Q_{dt} &= \delta(K_t^* - K_{t-1}) \\
K_t^* &= \alpha_0 + \alpha_1 HP_t + \alpha_2 INC_t + \alpha_3 POP_t + \alpha_4 OwnCost_t \\
Q_{st} &= \beta_0 + \beta_1 HP_t + \beta_2 HP_{t-1} + \beta_3 HP_{t-2} + \beta_4 ConCost_t \\
&\quad + \beta_5 MRate \\
Q_{dt} &= Q_{st} \qquad (1)
\end{aligned}$$

where, $Q_d$ ($Q_s$) is the log quantity of housing demanded (supplied), $K^*$ is the log of the desired housing stock, $K_{t-1}$ is the log of the housing stock in the previous period, and $\delta$ is the housing stock adjustment per period. In this setting, $Q_d$ is a function of the difference between the desired stock and the stock in the previous period. *HP* is the log of the price level of standard housing, *INC* is the log of urban household disposable income per capita, *POP* is the log of total residential population, *OwnCost* is the cost of home ownership, *ConCost* is the log of construction cost, and *MRate* is the mortgage interest rate that serves as a proxy for the development loan rate in the supply equation. The *t* subscript denotes year. As in Malpezzi and Maclennan (2001), we interpret the coefficients as elasticities. Therefore, $\beta_1$ is the price elasticity of housing supply.

Solving the set of equations in model (1) for the observable variable *HP* yields the following expression:

$$\begin{aligned} HP_t = {} & \frac{\delta\alpha_0 - \beta_0}{\beta_1 - \delta\alpha_1} + \frac{\delta\alpha_2}{\beta_1 - \delta\alpha_1} INC_t + \frac{\delta\alpha_3}{\beta_1 - \delta\alpha_1} POP_t \\ & + \frac{\delta\alpha_4}{\beta_1 - \delta\alpha_1} OwnCost_t - \frac{\delta}{\beta_1 - \delta\alpha_1} K_{t-1} \\ & - \frac{\beta_2}{\beta_1 - \delta\alpha_1} HP_{t-1} - \frac{\beta_3}{\beta_1 - \delta\alpha_1} HP_{t-2} \\ & - \frac{\beta_4}{\beta_1 - \delta\alpha_1} ConCost_t - \frac{\beta_5}{\beta_1 - \delta\alpha_1} MRate_t. \end{aligned} \tag{2}$$

Since the parameters on the right-hand side of Equation (2) cannot be identified directly, we estimate $\beta_1$ indirectly using values of the price elasticity ($\alpha_1$) and income elasticity ($\alpha_2$) of housing demand that we separately estimate from a reduced-form housing demand function (presented later in section 4.3). By incorporating a stochastic term, we derive the following reduced form housing price equation:

$$\begin{aligned} HP_t = {} & \gamma_0 + \gamma_1 INC_t + \gamma_2 POP_t + \gamma_3 OwnCost_t + \gamma_4 HP_{t-1} \\ & + \gamma_5 HP_{t-2} + \gamma_6 ConCost_t + \gamma_7 MRate_t + \gamma_8 K_{t-1} + \varepsilon_t. \end{aligned} \tag{3}$$

Thus, from Equations (2) and (3), we estimate the price elasticity of housing supply $\beta_1$ as:

$$\beta_1 = \delta\left(\frac{\alpha_2}{\gamma_1} + \alpha_1\right), \quad (4)$$

where $\gamma_1$ is the estimated elasticity of housing price with respect to income and $\delta$ is the parameter of stock adjustment speed that can be assigned artificially (as in prior studies). A higher (lower) $\delta$ would imply a more (less) responsive environment in which a larger (smaller) portion of the gap between the desired and actual stock will be filled through the construction process. Malpezzi and Maclennan (2001) set the parameter value of $\delta$ in their stock adjustment model for the U.S. and the U.K. as 0.3 or 0.6, depicting a moderate speed of adjustment. Note that a $\delta$ value of one would imply that the gap is fulfilled within a single period, which is the assumption underlying the flow model used by Mayo and Sheppard (1996), Malpezzi and Mayo (1997), and Malpezzi and Maclennan (2001).[6] Given the likelihood of construction lags in the housing market, the main results we report are based on the stock adjustment model.

## Data Sources and Description

The data covers macro-economic indicators as well as housing market variables in 35 major Chinese cities from 1998 to 2009. Due to the limited length of time-series data available, major cities are pooled to create a panel dataset that comprises of 35 cross-sections over a 12-year period, with a total count of 420 observations for each pooled variable.

*HP* (housing price level) is calculated using the Real Estate Price Index of 35 major cities published by the National Bureau of Statistics and the National Development and Reform Commission.[7] This index is transaction-based and is the best available annual housing price data in China for its wide coverage of sample cities as well as its length.[8] *HSTOCK* (housing stock *K*) is estimated by multiplying per capita floor area and residential population in the year 1999. We use 1999 because the *China City Statistical Yearbook* only reports the average floor area in 1999 and in some other selected years. Using the newly completed floor area in each year as the flow amount, the housing stock in each of the following years is estimated accordingly.[9]

*INC* is the urban household disposable income per capita and *POP* is the total residential population. *MRate* is a five-year lending rate, which we use to proxy for the development loan rate. It can also serve as a proxy for *OwnCost* (the real cost of homeownership) if we ignore expected housing price appreciation.[10] Thus, for our empirical analysis, we use *MRate* in place of *OwnCost* in Equation (3). Lastly, *ConCost* (the construction cost of housing development) is measured by dividing the material costs of completed housing units by the annual completed floor area. Thus this measure serves as a rough proxy of structure cost (excluding land and labor costs). The data for *INC*, *POP*, *MRate*, and *ConCost* are sourced from the *China Monthly Economic Indicators*, *China City Statistical Yearbook*, and *Statistic Yearbook* for various cities.

Appendix 1 presents the mean values of selected variables by city and region. The Appendix also provides the mean values of *INF* (the local inflation rate calculated from the local Consumer Price Index) as well as *NewStart* (the newly started floor area of residential housing) and *SaleArea* (the newly sold floor area of residential housing). All nominal values are deflated by the local CPI.

Prior to performing the empirical analysis, we conduct a pretest of the time-series properties of all the panel variables. Specifically, we employ the IPS test for unit root in each panel variable.[11] The tests for the panel indicate that the variables *HP*, *POP*, *MRate*, *HSTOCK*, *INF*, *and SaleArea* are integrated of order zero (i.e., stationary in levels) while *INC*, *ConCost*, and *Newstart* are integrated of order one (i.e., stationary in first difference). As some individual series have unit roots (or integrated of order one), we conduct a panel co-integration test to see if some (co-integrating) vector of coefficients exist to form a stationary linear combination of these variables.[12]

## *Empirical Analysis and Results*

The empirical analysis uses a panel data model whereby we impose a common coefficient on the price elasticity of housing supply across cities in a panel data setting to derive the national supply elasticity (which is similar to an average price elasticity of housing supply across all cities). This approach is intrinsically similar to that used by Harter-Dreiman (2004) and Grimes and Aitken (2010). As in these two studies, we use Quantitative Micro Software's EViews 6.0 to conduct all empirical estimations.

To estimate the price elasticity of housing supply $\beta_1$ in Equation (4), we first need to estimate the income elasticity of housing prices ($\gamma_1$) from Equation (3) and use this estimate together with estimated values of the price elasticity and income elasticity of housing demand ($\alpha_1$ and $\alpha_2$, respectively) and commonly used arbitrary values for $\delta$ to get a range estimate of $\beta_1$. We estimate $\gamma_1$ from the reduced form housing price Equation (3) expressed as a panel data model and incorporating a city-fixed effect.[13] Our co-integration test of the panel data using the Pedroni residual cointegration test indicates that all the variables in the equation are co-integrated. Therefore, a pooled least squares method is used to estimate the equation. Estimation of the panel model provides a statistically significant estimate of $\gamma_1 = 0.043$ ($t = 2.22$). Other coefficients in the equation, except $\ln(POP_{it})$ and $\ln(ConCost_{it})$, are also statistically significant based on White robust standard errors. (The model has an adjusted $R^2$ of 0.99 and a Durbin-Watson statistic of 1.85.) The model estimated without the two-year lag housing price variable also yields qualitatively similar results but has a DW statistic close to 1.[14] Therefore, the $\gamma_1$ estimate from the full model is used as an input to Equation (4).

We estimate $\alpha_1$ and $\alpha_2$ from a reduced-form housing demand function as specified below:

$$\ln(SaleArea_{it}) = \alpha_0 + \alpha_1 \ln(HP_{it}) + \alpha_2 \ln(INC_{it}) + \alpha_3 \ln(POP_{it}) + \alpha_4 MRate_{it} + \alpha_{5i} FE_i + \alpha_{6t} FE_t + \varepsilon_{it}, \quad (5)$$

where $SaleArea_{it}$ is the sold floor area in city $i$ at year $t$, which serves as a proxy for housing demand. $FE_i$ is a city-fixed effect, $FE_t$ is a year-fixed effect, and $\varepsilon_{it}$ is the error term for city $i$ at year $t$. The other independent variables (in city $i$ at year $t$) are as previously defined.[15] There are 420 observations (35 cities over 12 years: 1998–2009). Estimation of Equation (5) using a pooled least squares method provides statistically significant estimates of $\alpha_1 = -0.765$ ($t = -4.94$) and $\alpha_2 = 0.437$ ($t = 3.04$). The coefficients, $\alpha_3$ and $\alpha_{4,}$ are also statistically significant based on White standard errors.

It is noteworthy that the estimated values of $\alpha_1$ and $\alpha_2$ lie within the ranges assumed in the literature. Malpezzi and Maclennan (2001) assume $\alpha_1$ and $\alpha_2$ to be in the intervals (−0.5, −0.1) and (0.5, 1), respectively, for the U.S. and the U.K. Mayo and Sheppard (1996) assume $\alpha_1$ and $\alpha_2$ lie in the interval (−0.2, −0.5) and (0.5, 1), respectively, for Malaysia, Korea, and Thailand while Malpezzi and Mayo (1997) assume $\alpha_1$ and $\alpha_2$ lie in the interval (−0.5, −1) and (1, 1.5), respectively, for the same three countries.

Using the estimated value of $\gamma_1$ (0.043), the estimated values of $\alpha_1$ and $\alpha_2$ (−0.765 and 0.437, respectively) and arbitrary values of $\delta$ [set as 0.3 and 0.6 following Malpezzi and Maclennan, (2001)], we find from Equation (4) the implied price elasticity of supply $\beta_1$ to be 2.82–5.64.[16] Alternatively, using assumed values of $\alpha_1$ and $\alpha_2$ from Malpezzi and Mayo (1997) and Malpezzi and Maclennan (2001), we obtain estimates of $\beta_1$ of 3.3–13.9.

As a robustness check, we estimate an alternative model similar to the factor price-excluded reduced form housing price model used in Malpezzi and Maclennan (2001). This model has ln($HP$) as the dependent variable and only ln($INC$), ln($POP$), and $\ln(K_{t-1})$ as explanatory variables. We estimate the model with Cochrane–Orcutt correction (including both AR(1) and AR(2) to eliminate serial correlation).[17] The estimation yields $\gamma_1 = 0.091$ while the estimated $\alpha_1$ and $\alpha_2$ are −0.901 and 0.482, respectively. Setting $\delta$ to be 0.3 and 0.6, the implied price elasticity of the housing supply $\beta_1$ is 1.32–2.64.[18] $\beta_1$ is 1.5–6.5 using assumed values from Malpezzi and Mayo (1997) and Malpezzi and Maclennan (2001). Estimates from this alternative model are generally lower than those derived from the embellished model.

Exhibit 2 compares the elasticity estimates with that of other countries, while recognizing the broad ranges and imprecision of the estimates. Given that we

**Exhibit 2** | Comparison of Supply Elasticity Estimates Across Countries

| Countries | Period | Data | Source | Elasticity Estimate | Category |
|---|---|---|---|---|---|
| U.S. | Prewar | National | Malpezzi and Maclennan (2001) | 4.40~10.40 (flow) | Elastic |
| | Postwar ~1994 | National | Malpezzi and Maclennan (2001) | 5.60~12.70 (flow) | Elastic |
| | Postwar ~1994 | National | Malpezzi and Maclennan (2001) | 1.20~5.60 (stock) | Moderately Elastic |
| U.K. | Prewar | National | Malpezzi and Maclennan (2001) | 1.40~4.30 (flow) | Moderately Elastic |
| | Postwar ~1995 | National | Malpezzi and Maclennan (2001) | 0.00~0.50 (flow) | Inelastic |
| | Postwar ~1995 | National | Malpezzi and Maclennan (2001) | 0.00~0.50 (stock) | Inelastic |
| Korea | 1970~1986 | National | Malpezzi and Mayo (1997) | 0.00~0.17 (flow) | Inelastic |
| Malaysia | 1970~1986 | National | Malpezzi and Mayo (1997) | 0.07~0.35 (flow) | Inelastic |
| Thailand | 1970~1986 | National | Malpezzi and Mayo (1997) | ∞ (flow) | Highly Elastic |
| China | 1998~2009 | Aggregated across cities | This paper | 2.82~5.64 (stock)<br>5.96 (flow) | Moderately Elastic |

*Notes:* Flow stands for flow model while stock stands for stock adjustment model.

derived our aggregate elasticity estimate for China using the stock adjustment (as well as flow) models, Exhibit 2 only reports the comparative estimates from studies that use either of those two models. Studies (not reported in Exhibit 2) that use alternative estimation methods obtain a supply elasticity estimate of 1.1 for Hong Kong (Peng and Wheaton, 1994), near zero for the Netherlands (Vermeulen and Rouwendal, 2007), 0–0.84 for the U.K. (Meen, 2008), and 0.01 for New Zealand (Grimes and Aitken, 2010).

Comparing across countries (Exhibit 2), the price elasticity of the housing supply in China in 1998–2009 appears to be moderate and somewhat in line with the situation in postwar U.S. and prewar U.K. At the extremes, Thailand exhibits a highly elastic housing supply environment while Korea, Malaysia, and postwar U.K. exhibit inelastic housing supply. The Netherlands and New Zealand (not shown in Exhibit 2) also exhibit inelastic housing supply.

Prior comparative studies (Mayo and Sheppard, 1996; Malpezzi and Mayo, 1997; and Malpezzi and Maclennan, 2001) attribute the substantial variations in supply elasticities across countries to restrictive land use policies. Such international variations in supply elasticities and their correlation to regulatory practices hold true across cities in the U.S. as well (Green, Malpezzi, and Mayo, 2005). The implication of these findings is that the regulatory environment is an important determinant of the spatial variation in supply responsiveness.

## City-Specific Estimates and their Determinants

In this section we estimate supply elasticities at the city-level and identify their sources of variations. Note that cities across China exhibit significant local variation in topology, housing market maturity, and regulatory practices. The analysis proceeds in two stages. We first estimate the price elasticity of supply for each of the 35 cities using a variable-coefficient panel data model. In the second stage, we analyze their determinants by regressing the estimated supply elasticities on a set of explanatory variables.

### *Stage I Analysis and Results*

To estimate the city-level supply elasticity, we estimate new housing starts in response to changes in housing prices, while controlling for important cost shifters in a panel data model. The stock adjustment model (that we use to estimate national-level supply elasticity) has two limitations if used for estimating supply elasticity at the city-level. The first is the need to estimate or assign a speed of stock adjustment parameter $\delta$ for each city in order to obtain a point estimate (rather than a range of estimates) of supply elasticity for our cross-sectional regression analysis. (The point estimates of different cities are used as dependent variables in stage II.) Given that the speed of adjustment is affected by market fundamentals, which vary greatly across cities, it is unrealistic to impose an identical $\delta$ for all cities or to artificially assign a value for $\delta$ to estimate the supply elasticity of a city. Second, the length of the dataset (12 observations for each city) relative to the number of explanatory variables makes the stock adjustment model unsuitable for estimating city-level supply elasticity.[19]

Using the panel data set of 420 observations (35 cities over 12 years: 1998–2009), we estimate the price elasticity of supply at the city-level using a panel data model [as in Grimes and Aitken (2010)]. The equation is specified as follows:

$$\ln(NewStart_{it}) = \beta_0 + \beta_{1i} \ln(HP_{it}) + \beta_2 \ln(HP_{i,t-1}) + \beta_3 \ln(ConCost_{it}) + \beta_4 MRate_{it} + \beta_{5i} FE_i + \varepsilon_{it}, \quad (6)$$

where the variables (in city $i$ at year $t$) are as previously defined. $\beta_0$ is an overall constant term, $\beta_{1i}$ is the price elasticity of supply for city $i$, $\beta_{5i}$ incorporates city fixed-effects for city $i$, and $\varepsilon_{it}$ is the error term. The coefficients of *ConCost*, *MRate*, and $HP_{t-1}$ are restricted to be identical across cities.[20] Hence, the equation has only one unrestricted coefficient, $\beta_{1i}$, which reflects city-specific conditions. In other words, not only the intercepts would vary with city, the slope for $\ln(HP_{it})$ would also vary according to the city.[21] Given the short time series, we assume no significant temporal effects and, therefore, do not include a year-fixed effect in the model to conserve degrees of freedom in the estimation. The inclusion of a one-year lagged housing price variable in the model is consistent with the housing supply specification in Equation (1) and also helps alleviate the autocorrelation problem.[22] The inclusion of cost shifters (*ConCost* and *MRate*) in the housing supply equation is in line with prior studies (Topel and Rosen, 1988; Mayer and Somerville, 2000; and Meen, 2005).[23]

As before, a pretest of the panel data reveals that there is at least one co-integrated vector between the pooled variables in the equation. We estimate equation (6) by pooled least squares with White period standard errors, which are robust to serial correlation within cross-section and time-varying variances in the disturbances, and report the estimation results in Exhibit 3. (In Section 5.2, we discuss the results of a robustness check where we estimate the model using instrumental variables to address potential errors in variables problem as well as potential endogeneity problem between housing supply and housing prices.)[24]

As Panel A of Exhibit 3 shows, the signs of the coefficients of *ConCost* and *MRate* are in line with expectations. Panel B presents the key estimate, $\beta_{1i}$, which is the price elasticity of housing supply for city $i$. As the panel shows, all but three cities—Beijing, Shenzhen, and Kunming—exhibit significantly positive price elasticity of housing supply estimates.[25] The elasticity estimate is insignificant and close to zero for Beijing and Shenzhen while that for Kunming is significantly negative. The estimate for Shanghai is a low (but significantly positive) 1.52. It is noteworthy that Beijing, Shenzhen, and Shanghai (the three

**Exhibit 3** | Housing Supply Elasticity Estimates by City

Panel A: Estimates for Control Variables

| Variable | Coefficient |
|---|---|
| $ln(HP_{t-1})$ | −1.61** |
| $ln(ConCost)$ | −0.07 |
| *MRate* | −7.10*** |

Panel B: Estimates of the Price Elasticity of Housing Supply by City ($\beta_{1i}$)

| City | Elasticity Estimate | City | Elasticity Estimate |
|---|---|---|---|
| Xining | 37.05*** | *Tianjin* | 5.10*** |
| Yinchuan | 21.98*** | Lanzhou | 4.90*** |
| Changsha | 17.14*** | Wuhan | 4.66*** |
| Urumqi | 16.71*** | Chongqing | 4.51*** |
| Zhengzhou | 16.50*** | *Dalian* | 4.41*** |
| Hefei | 13.03*** | Chengdu | 4.36*** |
| *Guangzhou* | 12.62*** | *Fuzhou* | 3.85*** |
| Nanning | 11.45*** | *Xiamen* | 3.47*** |
| Guiyang | 9.71*** | *Nanjing* | 3.42*** |
| Huhhot | 9.63*** | *Qingdao* | 2.89*** |
| Taiyuan | 9.16*** | *Jinan* | 2.68*** |
| *Haikou* | 8.83*** | *Hangzhou* | 2.65*** |
| Xi'an | 8.04*** | *Ningbo* | 2.27*** |
| *Shijiazhuang* | 7.89*** | *Shanghai* | 1.52** |
| Nanchang | 6.78*** | *Beijing* | 0.53 |
| *Harbin* | 6.30*** | *Shenzhen* | 0.49 |
| *Shenyang* | 5.75*** | Kunming | −7.70*** |
| *Changchun* | 5.40*** | | |

Panel C: Statistics

| | | | |
|---|---|---|---|
| Adj. $R^2$ | 0.88 | F-Statistics | 40.78*** |

*Notes:* The table reports results from the estimation equation:

$$\ln(NewStart_{it}) = \beta_0 + \beta_{1i}\ln(HP_{it}) + \beta_2\ln(HP_{i,t-1}) + \beta_3\ln(ConCost_{it}) + \beta_4 MRate_{it} + \beta_{5i}FE_i + \varepsilon_{it}.$$

Equation is estimated using a pooled least squares method. City-fixed effects are included but not reported. There are 385 observations (35 cities over 11 years: 1999–2009). Statistical significance tests are based on White period standard errors. Cities in italics are the Eastern cities.

**Significant at the 5% level.

***Significant at the 1% level.

biggest housing sub-markets in China in terms of existing housing stock) exhibit rather large housing price appreciations but relatively small increases in housing starts during the sample period. At the extremes are Kunming (in the Western region) and Xining (in the Central region) with elasticity estimates of −7.70 and 37.05, respectively. Kunming is the only city in the sample experiencing a negative real housing price change (−4.6%) from 1998 to 2009 while Xining's phenomenal growth in housing development is fueled by the central government's ''Go West'' development policy implemented in early 2000 rather than by a change in demand for housing. Thus, we treat Kunming and Xining as outliers and exclude them from the stage II regression analysis.

The overall mean of the 33 city-level supply elasticity estimates (excluding Kunming and Xining) reported in Exhibit 3 is a significant 7.23 ($t = 7.90$). [Interestingly, this mean estimate is close to the mean of the 45 U.S. city-level supply elasticity estimates reported by Green, Malpezzi, and Mayo (2005), who also used a direct estimation approach to estimate the price elasticity of supply at the city-level.] A univariate comparison of the mean supply elasticities between the 18 Eastern cities and the 15 non-Eastern cities reveals that the housing supply responsiveness of the Eastern sub-group (mean elasticity = 4.45) is about half that of the non-Eastern sub-group (mean elasticity = 10.57). This difference in supply responsiveness may well reflect the difference in economic and regulatory features associated with Eastern versus non-Eastern cities. Generally, Eastern cities are economically more vibrant (with higher income and higher housing price levels) and have a more mature housing market (with a higher level of housing stocks) than non-Eastern cities (Appendix 1). In addition, the housing markets in the Eastern cities are generally subject to more stringent governmental regulations.

## Stage II Analysis and Results

*The Empirical Model and Data.* In this section we identify the sources of variation in supply elasticities across cities. We regress the estimated city-level supply elasticities on a set of explanatory variables classified under one of three categories: geographic, economic, and regulatory. The full regression model (with city-specific proxy variables from each category) is:

$$
\begin{aligned}
\beta_{1i} = {} & \theta_0 + \theta_1 DevelopableLandRatio_i + \theta_2 EAST_i \\
& + \theta_3 \ln(UrbanArea_{98\text{–}09,i}) + \theta_4 \Delta_{98\text{–}09} UrbanArea_i \\
& + \theta_5 \ln(POP_{98\text{–}09,i}) + \theta_6 \Delta_{98\text{–}09} POP_i + \theta_7 \ln(PopDensity_{03,i}) \\
& + \theta_8 \ln(HP_{98\text{–}09,i}) + \theta_9 GreenRatio_{98\text{–}09,i} + \theta_{10} \Delta_{98\text{–}09} Revenue_i \\
& + \theta_{11} ViolationRatio_{01\text{–}08,i} + \varepsilon_i. \qquad (7)
\end{aligned}
$$

**Exhibit 4** | Explanatory Variables and Descriptive Statistics

| Category | Variable | Mean | Std. Dev. |
|---|---|---|---|
| Geographic | *DevelopableLandRatio* | 86.53% | 9.83% |
| | $UrbanArea_{98-09}$ (Km$^2$) | 270.88 | 200.49 |
| | $\Delta_{98-09}$ *UrbanArea* | 8.47% | 3.72% |
| Economic | $POP_{98-09}$ (000s) | 6750.61 | 5381.43 |
| | $\Delta_{98-09}$ *POP* | 1.63% | 1.45% |
| | $PopDensity_{03}$ (person / km$^2$) | 1547 | 974 |
| | $HP_{98-09}$ (RMB / m$^2$) | 3745.86 | 1409.19 |
| Regulatory | $GreenRatio_{98-09}$ | 34.66% | 5.48% |
| | $\Delta_{98-09}$ *Revenue* | 19.43% | 4.40% |
| | $ViolationRatio_{01-08}$ | 1.56% | 1.42% |

*Notes:* Statistics are computed using data of 33 cities (excluding Xining and Kunming). *DevelopableLandRatio* is derived from the authors' computation. Data on land law violations are sourced from the 2001 to 2008 issues of the *China Land and Resources Statistic Yearbook*. Data for all other variables are extracted from various issues of the *China City Statistical Yearbook*. Variables are defined as follows: *DevelopableLandRatio* = proportion of land suitable for housing construction; $UrbanArea_{98-09}$ = average urban built-up area from 1998–2009; $\Delta_{98-09}$ *UrbanArea* = compound growth rate of urban built-up area from 1998 to 2009; $POP_{98-09}$ = total average registered residential population over the 1998–2009 period; $\Delta_{98-09}$ *POP* = compound growth rate of the total average registered residential population over the 1998–2009 period; $PopDensity_{03}$ = population density level in 2003; $HP_{98-09}$ = average housing price level during the 1998–2009 period; $GreenRatio_{98-09}$ = average ratio of green belt to urban built-up areas; $\Delta_{98-09}$ *Revenue* = compound growth rate of government revenues from 1998 to 2009; $ViolationRatio_{01-08}$ = fraction of the total land areas associated with land law violation cases in a province to its total urban built-up land area in 2008.

$\beta_{1i}$ is the estimated supply elasticity for each city $i$ derived from the stage I analysis. Two outlier cities (Kunming and Xining) were excluded. Exhibit 4 provides the descriptive statistics of the proxy variables in each category.

The city-specific geographic variables are *DevelopableLandRatio* (the proportion of land suitable for housing construction) and *EAST* (a dummy variable representing the Eastern cities). Note that a measure of the proportion of land suitable for development in cities in China is not available from any publications that we know. Therefore, as in Saiz (2010), we construct this measure using raw geographic data for each city in the sample. Appendix 2 describes the procedure used to calculate the developable land ratio while Exhibit 2.1 in Appendix 2 displays the data and the ranking of the cities based on the calculated developable land ratio.

The mean *DevelopableLandRatio* is about 87% (or 85% with Kunming and Xining included) and ranges from a low of 57% (for Fuzhou, an Eastern coastal city) to a high of 99% (for Yinchuan, a Central inland city). From Exhibit 3, Fuzhou has a housing supply elasticity estimate (3.85) that is about half that of the sample mean (7.23) while Yinchuan's estimate (21.98) is the second highest among the 35 cities. This observation conforms somewhat to our expectation of a positive correlation between the ratio of developable land and the price elasticity of housing supply.

The next six variables in the model are city-specific economic variables. $UrbanArea_{98-09}$ is the average urban built-up area and $\Delta_{98-09}$ *UrbanArea* is the annual compound growth rate of urban built-up area from 1998 to 2009. $POP_{98-09}$ and $\Delta_{98-09}$ *POP* are the total average registered residential population and its annual compound growth rate, respectively, over the 1998–2009 period. $PopDensity_{03}$ is the population density level in 2003.[26] $HP_{98-09}$ is the average housing price level during the 12-year period. Data for these economic variables are extracted from various issues of the *China City Statistical Yearbook.*

Generally, a city with a larger built-up urban area will have a lower potential land supply. Thus we would expect that as an urban built-up area increases, housing supply elasticity falls. Similarly, as the growth rate of urban built-up area rises, we would expect that the price elasticity of the housing supply falls. Following the theoretical model presented in Green, Malpezzi, and Mayo (2005), as the population of a city rises, the price elasticity of supply falls and as housing prices rise, so does the supply elasticity. However, as the authors note, the latter two relationships are somewhat ambiguous given the possibility of two-way causal flows between housing supply elasticity and the two variables. The rate of population growth, however, may influence builders' expectations and hence their supply decisions. Therefore, it is reasonable to expect that as population growth rate increases, so does supply responsiveness.

The last three variables are the city-specific regulatory variables. $GreenRatio_{98-09}$ is the average ratio of greenbelt to urban built-up areas. $\Delta_{98-09}$ *Revenue* is the compound growth rate of government revenues from 1998 to 2009 and $ViolationRatio_{01-08}$ is the fraction of the total land areas associated with land law violation cases in a province to its total urban built-up land area in 2008. Data for the green ratio and government revenues are extracted from various issues of the *China City Statistical Yearbook* while data on land law violations in each province are sourced from the 2001–2008 issues of the *China Land and Resources Statistic Yearbook.* Since there is no regulation index constructed for China, we use these three variables to proxy for government restrictions on land use and land transactions in each city. Generally, we would expect that as government restrictions on land use or land supply rises, housing supply elasticity falls.

The green ratio is part of a city's urban development policy. Although it may be possible to convert the usage of greenbelts to increase the supply of land for development, the political cost of such conversions could be rather high. As such, we would expect that as the green ratio rises, less land will be available for development and, hence, housing supply elasticity falls. The growth in municipal government revenues ($\Delta_{98-09}$ *Revenue*) may serve as an indicator of government restrictions on land supply given that revenues from land granting comprise a large share of the total government revenues. (For example, in 2009, China's government revenues from land granting comprise about 21% of the total revenues.) Thus, a higher growth in government revenues would imply lower government restrictions on land supply and, hence, higher supply elasticity. The incidence of land law violations ($ViolationRatio_{01-08}$) serves as an indicator of government restrictions on land transactions. Thus, a higher violation ratio would imply lower government restrictions and, hence, higher housing supply elasticity.

*Regression Results.* Exhibit 5 presents the results from four specifications of the regression model (7).[27] Model I incorporates all the variables specified in Equation (7), while the other three models include only selected explanatory variables from each of the three categories.

The Model I results show that only *DevelopableLandRatio* and $GreenRatio_{98-09}$ have a statistically significant relationship with supply elasticity and in the direction conforming to our expectations. Model II excludes selected insignificant variables and shows an improved adjusted $R^2$ over Model I. In this model, an additional three variables (East, urban built-up area, and population growth rate) are statistically significant and display their predicted signs. Excluding the *East* variable from Model II reduces the adjusted $R^2$ of the model from 49% to 43% and population growth rate becomes statistically insignificant, as shown in the Model III result. Instead, when *DevelopableLandRatio* is excluded from Model II, the adjusted $R^2$ of the model drops even further (from 49% to 41%) and the $GreenRatio_{98-09}$ becomes insignificant, as shown in Model IV result. The latter result lends some support to Saiz's (2010) finding that geography is a key determinant of housing supply elasticity.

We also perform a robustness check by generating a new set of supply elasticity estimates from an alternative specification of Equation (6) and use them as dependent variables in Equation (7). Specifically we estimate Equation (6) using a two-stage least squares approach in a panel data setting (as in Grimes and Aitken, 2010), whereby a one-year lagged (log) population, lagged (log) income, and lagged mortgage rate serve as instruments for the concurrent (log) housing price while the other exogenous variables serve as their own instrumental variables. The results (in terms of relative ranking of the cities based on their estimated supply elasticities) from the above specifications are qualitatively similar to those in Exhibit 3. Re-running Equation (7) using elasticity estimates from this specification shows *DevelopableLandRatio*, *East*, and $UrbanArea_{98-09}$ to be significant explanatory variables (adjusted $R^2$ of model = 38.4%). Excluding *East* from the regression model, *DevelopableLandRatio*, $GreenRatio_{98-09}$, $POP_{98-09}$, and $HP_{98-09}$ are significant explanatory variables (adjusted $R^2$ of model = 36.5%). Note that in comparison to Model II in Exhibit 5, these models have a much lower adjusted $R^2$, although the overall results are generally in line with that in Model II.

**Exhibit 5** | Determinants of Supply Elasticity

| | Dependent Variable (City-level Supply Elasticity Estimate) | | | |
|---|---|---|---|---|
| Independent Variable | Model I | Model II | Model III | Model IV |
| Intercept | 11.10<br>(0.36) | 17.41*<br>(1.90) | 22.18**<br>(2.39) | 28.43**<br>(3.33) |
| *DevelopableLandRatio* | 16.81**<br>(2.09) | 16.54**<br>(2.38) | 19.10**<br>(2.67) | |
| *East* | −2.98<br>(−1.33) | −3.12*<br>(−1.98) | | −3.82**<br>(−2.29) |
| $ln(UrbanArea_{98-09})$ | −2.35<br>(−1.01) | −2.74**<br>(−2.39) | −3.45**<br>(−3.02) | −2.37*<br>(−1.94) |
| $\Delta_{98-09}UrbanArea$ | −14.31<br>(−0.43) | | | |
| $ln(POP_{98-09})$ | −0.53<br>(−0.20) | | | |
| $\Delta_{98-09}POP$ | 114.29<br>(0.91) | 83.28*<br>(1.75) | 76.97<br>(1.54) | 92.12*<br>(1.80) |
| $ln(PopDensity_{03})$ | 0.28<br>(0.18) | | | |
| $ln(HP_{98-09})$ | 0.30<br>(0.07) | | | |
| $GreenRatio_{98-09}$ | −30.78*<br>(−1.90) | −27.85*<br>(−2.00) | −40.75***<br>(−3.14) | −23.51<br>(−1.57) |
| $\Delta_{98-09}Revenue$ | 21.78<br>(0.94) | | | |
| $ViolationRate_{01-08}$ | 19.57<br>(0.34) | | | |
| Adj. $R^2$ | 0.38 | 0.49 | 0.43 | 0.41 |
| F-Statistics | 2.80** | 7.09*** | 7.13*** | 6.38*** |

*Notes:* The dependent variable is the city-level supply elasticity estimate (excluding Xining and Kunming) as reported in Exhibit 3. The independent variables are defined as follows: *DevelopableLandRatio* = proportion of land suitable for housing construction; East = a dummy variable representing the Eastern sub-group of cities; ln($UrbanArea_{98-09}$) = Log of average urban built-up area from 1998–2009; $\Delta_{98-09}$ *UrbanArea* = compound growth rate of urban built-up area from 1998 to 2009; ln($POP_{98-09}$)= log of total average registered residential population over the 1998–2009 period; $\Delta_{98-09}$ *POP* = compound growth rate of the total average registered residential population over the 1998–2009 period; ln($PopDensity_{03}$) = log of population density level in 2003; ln($HP_{98-09}$) = log of average housing price level during the 1998–2009 period; $GreenRatio_{98-09}$ = average ratio of green belt to urban built-up areas; $\Delta_{98-09}$ *Revenue* = compound growth rate of government revenues from 1998 to 2009; $ViolationRatio_{01-08}$ = fraction of the total land areas associated with land law violation cases in a province to its total urban built-up land area in 2008. T-statistics are in parentheses. The number of observations is 33.

*Significant at the 10% level.

**Significant at the 5% level.

***Significant at the 1% level.

To summarize, the main regression result (based on Model II of Exhibit 5) suggests that generally cities in the non-Eastern region and those with higher developable land ratios, less built-up urban areas, higher population growth rates, and less restrictive land use regulations (as evidenced by a lower green ratio) display higher price elasticities of housing supply. The findings on population growth and land use regulation are consistent with Green, Malpezzi, and Mayo (2005), who examine regulatory and economic factors as potential determinants of supply elasticities across 45 U.S. cities.

It is important to note that the empirical results demonstrate that geographic, economic, and regulatory factors determine housing supply elasticity across cities. If this also holds true across countries, then the large variance in supply elasticity observed across countries could be a reflection of underlying differences in the geographic, economic, and regulatory environments in the different countries.

We estimated the average developable land ratio for 35 China's urban cities to be around 85%, which is higher than the 74% estimated by Saiz (2010) for U.S. metro areas.[28] Therefore, on average, China's cities seem to be less land constrained than U.S. cities, which would imply that China's supply environment should be more price elastic than that of the U.S. (holding other factors constant). However, regulatory and economic factors may also be at work. Compared to the U.S., China has more restrictive policies for housing and land transactions and also displays a more rapid rate of growth of built-up urban areas during the period examined. Therefore, considering all factors—geographic, regulatory, and economic—together, we find China's price elasticity of supply to be moderately elastic and somewhat in line with that in the U.S. Similar analysis could be extended to explain the variations in supply elasticities between other countries as well.

Note that the findings also have implications to our comprehension of the level and volatility of house prices observed in cities across China. Casual observation informs us that many of the cities in China that exhibit high house price appreciations are associated with low supply responsiveness (e,g., Beijing, Shanghai, and Shenzhen). Analyzing our data on 33 cities (excluding Kunming and Xining), we find a negative correlation of about 0.49 between the mean housing price level (from Appendix 1) and the housing supply elasticity in each city (from Exhibit 3).

## Concluding Remarks

Using data on 35 major cities in China, we estimate the price elasticities of housing supply at both the aggregated and city levels, as well as identify the factors that matter in determining supply elasticity. The findings reveal that, at the aggregated level, China's housing supply is moderately elastic (somewhat in line with postwar U.S. and prewar U.K.) but is less (more) price elastic than countries with liberal (highly restrictive) regulatory environments.

The analysis at the city-level reveals that geographical constraint, the average built-up urban area, the rate of population growth, and regulatory restrictions on land use matter in determining housing supply elasticities. These determinants, some of which are in line with past research, shed light on the reasons for the variations in housing supply responsiveness across cities and possibly across countries as well.

We calculate a developable land ratio from satellite-generated data for each of the 35 major cities in China and confirm a positive and significant relationship between the availability of developable land and housing supply elasticity. This geographical factor is also found to be one of the most important determinants of the price elasticity of housing supply. This finding suggests that housing supply elasticity is determined not only by housing market factors (such as built-up urban areas, house price levels, and regulatory constraints), but also by factors (such as pre-existing geographical constraints) that are exogenous to the housing market. This result should serve to motivate future studies to link geography to housing-related issues.

One shortcoming of our study is the limited length of the time-series data available on China. As more data become available, future studies could test the stability of the estimated parameters over a longer time horizon that encompasses upturns and downturns in the economy.

# Appendix 1

## Variable Means (1998–2009) by City and by Region

| City | *HP* Yuan / m² | *INC* Yuan | *POP* Million | *HSTOCK* $10^4$ m² | *ConCost* Yuan / m² | *INF* Rate | *NewStart* $10^4$ m² | *SaleArea* $10^4$ m² |
|---|---|---|---|---|---|---|---|---|
| Panel A: Eastern Cities | | | | | | | | |
| Beijing | 6551 | 14291 | 11.60 | 24758 | 1900 | 1.45% | 1727 | 1550 |
| Changchun | 2090 | 8558 | 7.22 | 4952 | 1435 | 1.33% | 484 | 260 |
| Dalian | 4675 | 10562 | 5.63 | 5432 | 1048 | 0.96% | 594 | 507 |
| Fuzhou | 4073 | 11281 | 6.09 | 4408 | 1110 | 1.20% | 456 | 413 |
| Guangzhou | 6368 | 17256 | 7.35 | 8382 | 1438 | 0.67% | 467 | 817 |
| Haikou | 2160 | 9532 | 1.49 | 1170 | 2653 | 0.92% | 104 | 103 |
| Hangzhou | 5372 | 14299 | 6.47 | 7379 | 1261 | 1.12% | 703 | 603 |
| Harbin | 2398 | 8772 | 9.60 | 5514 | 974 | 1.03% | 448 | 387 |
| Jinan | 3485 | 11777 | 5.84 | 5121 | 1064 | 1.17% | 294 | 213 |
| Nanjing | 4567 | 12931 | 5.80 | 5811 | 1242 | 1.22% | 640 | 558 |
| Ningbo | 5388 | 15411 | 5.52 | 3608 | 979 | 1.23% | 504 | 440 |
| Qingdao | 3541 | 11227 | 7.30 | 5281 | 1311 | 1.66% | 709 | 531 |
| Shanghai | 6101 | 15739 | 13.50 | 25278 | 1004 | 1.47% | 2173 | 2218 |
| Shenyang | 2830 | 9591 | 6.95 | 8733 | 1961 | 0.96% | 985 | 644 |
| Shenzhen | 6647 | 23077 | 1.68 | 14861 | 1987 | 1.24% | 593 | 460 |

## Appendix 1 (continued)

## Variable Means (1998–2009) by City and by Region

| City | *HP* Yuan / $m^2$ | *INC* Yuan | *POP* Million | *HSTOCK* $10^4$ $m^2$ | *ConCost* Yuan / $m^2$ | *INF* Rate | *NewStart* $10^4$ $m^2$ | *SaleArea* $10^4$ $m^2$ |
|---|---|---|---|---|---|---|---|---|
| Shijiazhuang | 2760 | 8906 | 9.19 | 3020 | 945 | 1.43% | 271 | 171 |
| Tianjin | 4061 | 11626 | 9.34 | 11836 | 1081 | 1.14% | 1042 | 842 |
| Xiamen | 6193 | 14196 | 1.48 | 2689 | 1012 | 1.27% | 296 | 250 |
| Mean | 4403 | 12724 | 6.78 | 8235 | 1356 | 1.19% | 694 | 609 |
| Panel B: Non-Eastern Cities | | | | | | | | |
| Changsha | 3002 | 10834 | 6.14 | 3819 | 1124 | 1.43% | 585 | 476 |
| Hefei | 3259 | 9137 | 4.56 | 2692 | 1620 | 1.15% | 493 | 434 |
| Huhhot | 1931 | 9780 | 2.15 | 1956 | 1340 | 1.78% | 250 | 149 |
| Nanchang | 3217 | 8328 | 4.60 | 2630 | 790 | 1.78% | 271 | 219 |
| Taiyuan | 3303 | 8958 | 3.28 | 3169 | 1615 | 1.56% | 145 | 96 |
| Wuhan | 2733 | 10227 | 7.86 | 11694 | 1027 | 0.94% | 784 | 599 |
| Zhengzhou | 2682 | 9224 | 6.62 | 4076 | 918 | 1.72% | 567 | 431 |
| Chengdu | 3895 | 10507 | 10.60 | 8672 | 1237 | 1.31% | 1025 | 1032 |
| Chongqing | 3027 | 9629 | 31.50 | 16835 | 1136 | 0.82% | 1718 | 1558 |
| Guiyang | 3045 | 8803 | 3.43 | 3260 | 1130 | 1.08% | 307 | 277 |

## Appendix 1 (continued)
## Variable Means (1998–2009) by City and by Region

| City | *HP* Yuan / $m^2$ | *INC* Yuan | *POP* Million | *HSTOCK* $10^4$ $m^2$ | *ConCost* Yuan / $m^2$ | *INF* Rate | *NewStart* $10^4$ $m^2$ | *SaleArea* $10^4$ $m^2$ |
|---|---|---|---|---|---|---|---|---|
| Kunming | 2877 | 8910 | 4.94 | 4164 | 1204 | 1.91% | 382 | 426 |
| Lanzhou | 2562 | 7719 | 3.05 | 2583 | 1239 | 1.13% | 149 | 128 |
| Nanning | 2639 | 9479 | 6.49 | 2660 | 1131 | 1.19% | 306 | 291 |
| Urmuqi | 2775 | 9072 | 1.91 | 3001 | 976 | 1.13% | 175 | 243 |
| Xian | 3747 | 9480 | 7.23 | 5591 | 1408 | 0.71% | 494 | 448 |
| Xining | 2031 | 7194 | 1.96 | 1432 | 1211 | 2.03% | 88 | 70 |
| Yinchuan | 2538 | 7998 | 1.28 | 1633 | 1041 | 1.77% | 136 | 161 |
| Mean | 2899 | 9134 | 6.33 | 4698 | 1185 | 1.38% | 463 | 414 |

*Notes:* The data sources are various issues of *China Monthly Economic Indicators*, the *China City Statistical Yearbook*, and the *Statistic Yearbook* of different cities. Data shown are in nominal values. *HP* is the price level of standard housing service, *INC* is the urban household disposable income per capita, *POP* is the total residential population, *HSTOCK* is housing stock, *ConCost* is the construction cost, *INF* is the local inflation rate calculated from the local Consumer Price Index, *NewStart* is the newly started floor area of residential housing, and *SaleArea* is the newly sold floor area of residential housing.

## Appendix 2

## Computing the Developable Land Ratio of 35 China Cities

As in Saiz (2010), we process satellite-generated data on terrain elevation and presence of water bodies to precisely estimate the amount of developable land in each Chinese city. We use the ASTER Global Digital Elevation Model (ASTER GDEM) generated by the Ministry of Economy, Trade, and Industry of Japan (METI) and the National Aeronautics and Space Administration (NASA). ASTER GDEM is the newest and most integrated DEM data that is acquired by a satellite-borne sensor ''ASTER'' to cover all the land on earth updated to June 30, 2009.

Using ArcGIS 9.2 software, we generate slope maps for the 35 Chinese cities. Once we know the built-up area of each city, we can calculate the conceptual city radius (i.e., the radius that makes a circle have a similar area as an urban built-up area) accordingly. The real city radius we use to calculate the developable land ratio is three times the conceptual city radius since not every city is mono-centric. We assume that three times the conceptual city radius could well encompass most of the built-up urban area. The average real radius for the 35 cities is 30.50 kilometers, a little smaller than the 50 kilometers that Saiz (2010) applies to all U.S. metropolitan areas.

To obtain the developable land ratio, we need to calculate the proportion of land areas that has a slope below 15%. Saiz (2010) believes that such a site condition is suitable for real estate development**.** Exhibit 2.1 shows the inputs we use to calculate the developable land ratio for the 35 cities in our sample. Since the ArcGIS 9.2 software can automatically calculate the slope of a cell and report the number of cells with certain conditions, we just have to multiply the ''number of cells $>$ 15%'' by 900m$^2$ to get the ''area of cells $>$ 15%.'' (A cell is a square on the earth surface with 30 meters long on each side. The grid map of each city's urban area consists of a lot of cells.)

For greater precision, we use the remote-sensing interpretation ETM data to calculate the urban areas that are covered by inland water such as wetlands, rivers, or lakes. In addition, we use digital contour maps to calculate the area within the city radius that is lost to oceans and then delete these areas from the total urban areas to get the urban area with ocean adjustment. The last column in Exhibit 2.1 shows the developable land ratio, which is equal to unity minus the proportion of cells$>$15% (column 2 divided by column 6).

**Exhibit 2.1** | Inputs to Calculate the Developable Land Ratio of 35 Chinese Cities

| City | Number of Cells > 15% | Area of Cells > 15% | Area of Water Bodies | Real City Radius | Urban Area with Ocean Adjustment | Proportion of Cells < 15% (DevelopableLandRatio) |
|---|---|---|---|---|---|---|
| Unit | | $Km^2$ | $Km^2$ | Km | $Km^2$ | Rate |
| Yinchuan | 1606 | 1.45 | 8.51 | 17.83 | 998.74 | 99.00% |
| _Shenyang_ | 55184 | 49.67 | 16.17 | 32.56 | 3330.57 | 98.02% |
| _Shanghai*_ | 7561 | 6.80 | 116.07 | 50.38 | 6067.26* | 97.97% |
| Zhengzhou | 47739 | 42.97 | 51.66 | 30.70 | 2960.92 | 96.80% |
| _Harbin_ | 18985 | 17.09 | 84.52 | 31.21 | 3060.11 | 96.68% |
| _Changchun_ | 70667 | 63.60 | 34.89 | 30.65 | 2951.28 | 96.66% |
| _Haikou*_ | 191 | 0.17 | 17.93 | 16.15 | 490.56* | 96.31% |
| _Shijiazhuang_ | 56440 | 50.80 | 22.73 | 23.39 | 1718.74 | 95.72% |
| Chengdu | 217271 | 195.54 | 15.00 | 35.02 | 3852.85 | 94.54% |
| Xian | 132762 | 119.49 | 31.18 | 27.97 | 2457.73 | 93.87% |
| _Tianjin_ | 9431 | 8.49 | 363.90 | 42.85 | 5768.35 | 93.54% |
| Changsha | 115367 | 103.83 | 86.90 | 26.38 | 2186.25 | 91.28% |
| Hefei | 41414 | 37.27 | 219.15 | 28.32 | 2519.63 | 89.82% |
| Urumqi | 375747 | 338.17 | 9.15 | 29.46 | 2726.56 | 87.26% |
| _Nanjing_ | 511816 | 460.63 | 249.13 | 41.18 | 5327.49 | 86.68% |
| _Guangzhou_ | 486301 | 437.67 | 649.12 | 50.64 | 8056.33 | 86.51% |
| _Xiamen*_ | 133322 | 119.99 | 14.94 | 23.76 | 992.80* | 86.41% |
| _Dalian*_ | 127889 | 115.10 | 17.41 | 27.19 | 912.43* | 85.48% |
| Huhhot | 225635 | 203.07 | 0.68 | 21.00 | 1385.44 | 85.29% |

**Exhibit 2.1** | (continued)

Inputs to Calculate the Developable Land Ratio of 35 Chinese Cities

| City | Number of Cells > 15% | Area of Cells > 15% | Area of Water Bodies | Real City Radius | Urban Area with Ocean Adjustment | Proportion of Cells < 15% (DevelopableLandRatio) |
|---|---|---|---|---|---|---|
| Unit | | Km$^2$ | Km$^2$ | Km | Km$^2$ | Rate |
| *Jinan* | 425124 | 382.61 | 56.45 | 30.56 | 2933.98 | 85.04% |
| *Beijing* | 2015791 | 1814.21 | 62.92 | 61.28 | 11797.43 | 84.09% |
| Nanchang | 93262 | 83.94 | 73.75 | 17.67 | 980.90 | 83.92% |
| Nanning | 255267 | 229.74 | 36.10 | 22.65 | 1611.71 | 83.51% |
| Wuhan | 142789 | 128.51 | 565.00 | 36.34 | 4148.77 | 83.28% |
| *Hangzhou* | 419882 | 377.89 | 178.33 | 32.43 | 3304.03 | 83.17% |
| *Qingdao** | 167355 | 150.62 | 6.87 | 27.66 | 932.14* | 83.10% |
| *Ningbo* | 415009 | 373.51 | 62.76 | 26.33 | 2177.97 | 79.97% |
| Taiyuan | 461479 | 415.33 | 14.67 | 26.11 | 2141.72 | 79.92% |
| *Shenzhen** | 534371 | 480.93 | 140.35 | 47.51 | 3019.47* | 79.42% |
| Guiyang | 274178 | 246.76 | 16.23 | 20.03 | 1260.41 | 79.13% |
| Chongqing | 1475105 | 1327.59 | 117.48 | 45.04 | 6373.04 | 77.33% |
| Kunming | 952089 | 856.88 | 25.18 | 28.07 | 2475.34 | 64.37% |
| Xining | 244933 | 220.44 | 0.09 | 13.75 | 593.96 | 62.87% |
| Lanzhou | 744319 | 669.89 | 16.34 | 22.90 | 1647.48 | 58.35% |
| *Fuzhou* | 604954 | 544.46 | 134.44 | 22.52 | 1593.26 | 57.39% |

*Notes:* An asterisk denotes cities with ocean part within its city radius. The areas of these cities exclude the ocean area. Cities in italics are the Eastern cities. A cell is a square on the earth surface with 30 meters (resolution of ASTER GDEM) long on each side.

## Endnotes

[1] The statistics are calculated from housing price level data (published by the National Bureau of Statistic and National Development and Reform Commission) on the 35 cities in China we study. We categorize these 35 cities into East, West, and Central regions and then compute the average housing price appreciation rates in each region.

[2] The land-use right transaction reform launched in March 2004 in China specifies that all state-owned urban land for real estate development can be granted only through tender, oral or listing auctions while the supply structure policy launched in May 2006 requires units with floor area less than 90 square meters to cover 70% of the total floor area in all newly registered or constructed projects.

[3] This type of model has also been applied to retail space investment (e.g., Benjamin, Jud, and Winkler, 1998a, 1998b).

[4] Although Topel and Rosen's (1988) theoretical model is based on the stock-flow theory, their empirical model does not include a housing stock proxy, thus making it more similar to a $q$ theory empirical model.

[5] This specification is in line with prior studies such as Topel and Rosen (1988), Mayo and Sheppard (1996), and Jud and Winkler (2002).

[6] Comparing to Equation (1) of the stock adjustment model, the flow model is a three equation model without the terms $K^*$, $K_{t-1}$, and $\delta$, and has $Q_d$ in place of $K^*$ in the equation.

[7] The housing price level is used rather than the index for the analysis as it contains more cross-city information than the index. In 2005, the National Bureau of Statistics and the National Development and Reform Commission published the price level of each city, enabling us to transform the price index to price level.

[8] The China Real Estate Index System (CREIS) also provides transaction-based housing price index data but it covers only ten major cities in China prior to 2000.

[9] In other words, the series after 1999 is computed by adding newly built floor areas to the figure in the previous year. To simplify computation, we assume no deterioration in the housing stock.

[10] Note that *OwnCost* = Nominal *MRate* + Maintenance cost + Property tax − Inflation − $HP^e/HP$, where $HP^e$ is the expected housing price. In China, maintenance cost does not vary much across time and region. Also, there is no enacted property tax during the sample period. If we assume a constant rate of expected housing price appreciation across time and region, then the real rate of lending (*MRate* = Nominal *MRate* − Inflation) will fully capture the dynamics of home ownership cost (*OwnCost*).

[11] The IPS test, put forth by Im, Pesaran, and Shin (2003), claims to be particularly useful for situations involving a short time series and a large number of cross-sections.

[12] Co-integration refers to co-movements of variables in the long run and co-integrated variables would have a stable long-run relationship.

[13] The specification of the panel data model is:

$$HP_{it} = \gamma_0 + \gamma_1 INC_{it} + \gamma_2 POP_{it} + \gamma_3 MRate_{it} + \gamma_4 HP_{i,t-1} + \gamma_5 HP_{i,t-2} + \gamma_6 ConCost_{it} + \gamma_7 K_{i,t-1} + \gamma_{8i} FE_i + \varepsilon_{it},$$

where $FE_i$ is a city-fixed effect and $\varepsilon_{it}$ is the error term for city $i$ at year $t$. The other variables (in city $i$ at year $t$) are as previously defined. All the variables are in natural logarithms. There are 350 observations (35 cities over 10 years: 2000–2009) for the above model with two lags in housing price.

14 We also examined a three-year lag in housing prices but find the coefficient of this variable to be insignificant.

15 The Pedroni test reveals that the five variables in Equation (5) are co-integrated. The detailed test results are available upon request.

16 We also estimate a flow version of this model and obtain an estimate of $\gamma_1 = 0.065$. Using the same estimates of $\alpha_1$ and $\alpha_2$ as that used for the stock adjustment model, we obtain a price elasticity of housing supply measure of 5.96 (reported in Exhibit 2).

17 Malpezzi and Maclennan (2001) use the Cochrane–Orcutt correction to solve the serial correlation problem by adding AR(1) into the model. Note that, in our embellished model, the incorporation of lagged values of housing prices into the price equation took care of the serial correlation problem.

18 We obtain an estimate of $\gamma_1 = 0.165$ for the flow version of this model. Using the same estimates of $\alpha_1$ and $\alpha_2$ as that used for the stock adjustment model, we obtain a price elasticity of the housing supply measure of 2.02 for this flow model.

19 For example, when we incorporate two lags of housing price into the supply equation in the stock adjustment model (see Equation (1)), we have 14 regression coefficients for each city.

20 The bank lending mortgage rate, which is modulated by the People's Bank of China, is identical across different regions. Although construction costs may vary in level across regions, they share a common trend and account for a similar percentage of the total housing price. $HP_{t-1}$ is assumed to share a similar correlation pattern within a national housing investment market.

21 We estimate Equation (6) using EViews 6.0. EViews estimates the equation by internally creating interaction variables between each city $i$ ($i = 1, 2, ...., 35$) and the cross-section specific regressor $\ln(HP_{it})$, and use them in the regression. In other words, the regression output has 35 slope coefficients, $\beta_{1i}$, one for each of the 35 cities in the sample.

22 Including a lagged (log) *HP* variable in the equation results in an improvement in the Durbin-Watson (DW) statistics from 1.17 (without the lagged *HP* variable) to 1.31. Further adding lagged *MRate* and lagged (log) *ConCost* into the equation yields a slightly higher DW statistic (1.43) but the regression results are qualitatively similar to those we report.

23 Some studies (e.g., Apgar and Masnick, 1991) also suggest examining factors that determine long-term construction costs when forecasting housing starts.

24 Note, however, that the simultaneous response of prices to supply is unlikely to be a serious problem because new constructions or starts are usually such a small fraction of the existing stock.

25 It is noteworthy that Green, Malpezzi, and Mayo (2005) obtain significant positive supply elasticity estimates in 48.9% of 45 U.S. MSAs while Goodman and Thibodeau (2008), using a one-tailed test, find significant positive supply elasticities in 63.2% for the 133 U.S. cities they study.

26 We use the value in 2003 (in the middle of the 12-year period) as the proxy for this variable as data for this variable are not available for more recent years. Also, the data show little variation in population density during the sample period.

[27] We have only two insignificant elasticity estimates with values close to zero (Exhibit 3) that we use in the regression. Note that Green, Malpezzi, and Mayo (2005) use all their elasticity estimates (including negative as well as insignificant values) in their regression analysis.

[28] We compute the average developable land ratio for U.S. metro areas using the estimates of undevelopable land areas for 95 U.S. MSAs presented in Table 1 of Saiz's (2010) paper. We average the ratios and treat the average as representative of the developable land ratio in U.S. urban areas.

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