Residential Land Use Regulation and the US Housing Price Cycle Between 2000 and 2009

Haifang Huang* and Yao Tang†

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Abstract

In a sample covering more than 300 cities in the US from January 2000 to July 2009, we find that more restrictive residential land use regulations and geographic land constraints are linked to larger booms and busts in housing prices. The natural and man-made constraints also amplify price responses to the subprime mortgage credit expansion during the decade, leading to greater price increases in the boom and subsequently bigger losses. Contrary to prior literature, our findings indicate a significant link between supply inelasticity and price declines during the bust, whereas Glaeser, Gyourko, and Saiz (2008) found little evidence of such a relationship from an earlier downturn from 1989 to 1996.

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1 Introduction

Large swings in asset prices are a concern for macroeconomic stability. The volatility of housing prices appears particularly destabilizing, as housing busts typically

*Corresponding author. Department of Economics, University of Alberta, HM Tory 8-14, Edmonton, AB T6G 2H4, Canada. Email address: haifang.huang@ualberta.ca. We thank Stuart S. Rosenthal (editor) and two anonymous reviewers for their invaluable input. We are also grateful for the comments and help, in various forms, from Matthew Delaney, David D. Foster, Stuart Landon, Ke Pang, Laura Turner, Anna Williams and seminar participants at the University of Alberta, the First Colby-Bates-Bowdoin Annual Economics Conference, the University of Tsukuba and the 2010 meeting of the Canadian Economics Association. All errors in the paper are ours.

†Department of Economics, Bowdoin College, 9700 College Station, Brunswick, Maine 04011-8497, USA. Email address: ytang@bowdoin.edu.

involve a larger loss in GDP than equity busts (Helbling and Terrones, 2003). An important factor behind the cyclical dynamics of housing prices is housing supply conditions (Capozza et al., 2004; Malpezzi and Wachter, 2005; Glaeser et al., 2008). In this paper, we empirically examine the relationship between housing supply constraints and the amplitude of price swings across US local housing markets between 2000 and 2009, focusing on two specific questions.

The first question is whether supply constraints are related to greater price busts after 2006. While the literature has consistently documented a positive relation between supply restrictions and the size of price booms, the evidence regarding busts is weaker. A recent study, Glaeser et al. (2008), reported little correlation between geographic land scarcity and the fall in house prices over the 1989-1996 US housing bust. Our paper will revisit the relation using data that includes the three years of housing downturn from 2006 to 2009.

The second question is whether supply inelasticity exacerbated the boom-bust consequences of the subprime mortgage credit expansion over the past decade. Mian and Sufi (2009) presented evidence that the extension of mortgage credit to borrowers with low credit quality was an important driver of the housing cycle. Here, we ask whether the impact of the credit expansion depended on supply conditions in the housing market.

We consider two types of supply restrictions: residential land use regulations and geographic land scarcity. We are primarily interested in the former; the inclusion of the land information acknowledges the possibility that land scarcity begets regulations.[1]

From a sample of more than 300 cities in the US, we find that both regulatory and geographic constraints contributed to the amplitude of price booms and busts

[1] See Saiz (2010), Malpezzi et al. (1998) and the references within.

between 2000 and 2009. We also find that local dependence on subprime mortgages was more destabilizing in cities that face greater supply restrictions. Unlike Glaeser et al. (2008), who found little correlation between supply elasticity and price declines during the 1989-1996 housing bust, we find that supply constraints amplified the fall in house prices from 2006 to 2009. Further examination indicates that the difference is due to sample periods.

The structure of the paper is as follows: Section 2 reviews the literature. Section 3 describes the empirical model and data. Section 4 presents the results. Section 5 contains a series of robustness tests and a comparison between the 2006-2009 housing bust and the 1989-1996 bust. Section 6 concludes.

2 Literature review

The focus of this paper is housing supply, a subject that historically has been understudied relative to housing demand (Rosenthal, 1999). Research on housing supply has grown substantially in recent years. Many studies focus on housing supply regulations (e.g., Glaeser et al., 2005; Quigley and Raphael, 2005; Green et al., 2005; Ihlanfeldt, 2007; Glaeser and Ward, 2009).[2] Saiz (2010) studied constraints imposed by geography, providing estimates of land scarcity for major US metropolitan areas. These recent studies consistently reported that supply constraints, including land use regulations, are associated with higher housing costs, faster price growth, less new construction or a lower degree of supply elasticity.

Our paper differs from most of the studies cited above in that we focus on short-run fluctuations in house prices, asking whether supply constraints are associated with greater price booms and busts. In terms of research questions, our paper is close to Capozza et al. (2004), Malpezzi and Wachter (2005) and, in particular,

[2] Quigley and Rosenthal (2005) reviews empirical studies before 2004.

Glaeser et al. (2008).[3]

Capozza et al. (2004) estimated the serial correlation and the mean reversion coefficients for housing prices in a panel of US metropolitan areas between 1979 and 1995. They reported that higher construction costs were associated with higher serial correlation and lower mean reversion, presenting conditions for price overshooting. Malpezzi and Wachter (2005) constructed a model featuring speculative demand from adaptive expectations. Their model predicts larger price swings in markets with lower supply elasticity. Using metro-level data from 1979 to 1996, they reported a positive relation between the stringency of housing supply regulations and the standard deviation of changes in house prices. Our paper will add to this body of evidence using episode analysis, relating housing supply restrictions to the housing cycle in the past decade and the underlying subprime credit expansion, phenomena notable for their significant consequences.

Glaeser et al. (2008) constructed a model of housing bubbles that features temporary increases in optimism and adaptive expectations. In their model, the duration and magnitude of housing bubbles are endogenous to housing supply elasticity, because homebuyers' expectations of future price growth are influenced by past growth, which in turn is influenced by the supply elasticity. The model predicts greater price increases in inelastic areas during booms, but makes ambiguous predictions regarding the relationship between supply inelasticity and the size of post-bubble price corrections. The ambiguity arises from two conflicting forces. On the one hand, supply constraints limit new construction in booms, thus lessening downward pressure on prices in busts. On the other hand, house prices rise more substantially in inelastic areas during booms, creating demand from adaptive expectations that exacerbates the busts. Empirically, the researchers found little

[3] We are aware of at least one mimeo, Hilber and Vermeulen (2009), that links housing supply constraints to house price volatility. They use data from England.

correlation between the measure of geographical constraints, due to Saiz (2010), and the size of price declines during the 1989-1996 US housing bust.

In our paper, the sample period covers the 2006-2009 housing downturn that is not included in Glaeser et al. (2008). The addition of new data provides another chance to examine the relationship between housing supply conditions and price corrections in downturns. There are substantial differences over time. The 2006-2009 price bust is more pronounced than the one during the period of 1989 to 1996; the fall in real house prices at the national level is 14 percent versus 6 percent.[4] Furthermore, the share of land cost in home value has risen substantially since the 1980s (Davis and Palumbo, 2008). Given the increased importance of land, factors that affect land values, such as supply restrictions, likely have become more important in shaping the dynamics of the recent housing cycle. This, together with a cycle that is more pronounced, will make it easier to detect a relationship between supply elasticity and price busts, if there is any. As declines in house prices have implications on household consumption (e.g., Case et al., 2005; Campbell and Cocco, 2007), business startups (Black et al., 1996), labor mobility (Ferreira et al., 2010) and the functioning of the banking system (Helbling and Terrones, 2003; Trichet, 2005), it is important to understand what factors contribute to house price busts.

3 Empirical specification and data

3.1 The empirical specification

This paper studies the US housing cycle between 2000 and 2009, a phenomenon in part driven by an expansion of subprime mortgage credit supply in the early to mid-2000s. The model behind our empirical specification assumes that cities had different supply conditions in the housing market. It also assumes that the na-

[4] Authors' calculation based on the FHFA index for USA. The inflation adjustment uses national CPI index net of shelter.

tionwide subprime credit expansion had different local impacts on housing demand, since some cities were more dependent on subprime credit than others. We will examine the relation between supply elasticity and the amplitude of price swings during the period. We also ask whether the housing demand arising from the subprime expansion had greater boom-and-bust impacts in cities that are more supply restricted.

We use both regulatory and geographic restrictions to indicate supply constraints in the housing market. To measure local dependence on subprime mortgages, we follow Mian and Sufi (2009) and use the rejection rates of mortgage applications in 1996. If a city had a higher level of rejection rate before the expansion, we assume that it had a greater share of residents with low credit quality. The subprime expansion lowered the lending standard, providing previously unqualified borrowers access to mortgage loans. We hypothesize that this will lead to a greater increase in housing demand in cities where the pool of low-quality borrowers was bigger, as inferred from a higher rejection rate before the expansion. To test for robustness, we use an alternative proxy measuring the prevalence of risky mortgage loans during the housing boom, namely the share of mortgage loans that carried high interest-rate spreads.

Our empirical model, which also includes contemporaneous economic variables

and other controls, is described by the following two equations:

$$\begin{aligned}
\Delta price_{i,boom} &= \alpha_0 + \alpha_c \cdot reject_i + \alpha_r \cdot regulation_i + \alpha_g \cdot geographic\ constraint_i \\
&\quad + \alpha_{cr} \cdot reject_i \cdot regulation_i + \alpha_{cg} \cdot reject_i \cdot geographic\ constraint_i \\
&\quad + \alpha_X \cdot X_{i,boom} + u_{i,boom} \\
\Delta price_{i,bust} &= \beta_0 + \beta_c \cdot reject_i + \beta_r \cdot regulation_i + \beta_g \cdot geographic\ constraint_i \\
&\quad + \beta_{cr} \cdot reject_i \cdot regulation_i + \beta_{cg} \cdot reject_i \cdot geographic\ constraint_i \\
&\quad + \beta_X \cdot X_{i,bust} + u_{i,bust},
\end{aligned}$$

where the subscript i indexes cities and the subscripts *boom* and *bust* indicate phases in the housing cycle. The vector of control variables, X_i, includes percentage changes in employment and percentage changes in median household income (the latter is available only for the boom equation), as well as the city profile in the 2000 Census, including population density, population size, average household income, the share of urban population, the unemployment rate and the proportion of vacant housing units.

The key feature of the specification is that we break the price movements between 2000 and 2009 into two phases: an initial boom and a bust afterward. The price changes are the dependent variables. Our focus is on the two supply constraints and their interactions with the mortgage rejection rate (or the share of high-cost mortgages). The interactive terms allow the price impacts of the subprime expansion to depended on housing supply conditions.

3.2 Data and descriptive statistics

The unit of observation in our main regression is incorporated cities with at least 10,000 residents in the 2000 Census. The dependent variables are changes in the city-level Home Value Index from Zillow. Zillow provides estimates of prices for

individual houses in US urban areas, using data that include public records and local area market conditions. The estimates have been shown to have good accuracy by the media and academic literature.[5] We also use the Federal Housing Finance Agency House Price Index (hereafter the FHFA index), which is published at the metropolitan level, for some of our analysis. There is a high correlation between the Zillow index, aggregated to the metropolitan level, and the FHFA index. In the largest overlapped sample of 210 metropolitan areas, the correlation coefficient is 0.93 for price changes from 2000 to 2006, and 0.90 for changes from 2006 to 2009.

The index for regulatory land restriction is the Wharton Residential Land Use Regulatory Index (WRLURI) from Gyourko et al. (2008). WRLURI is a municipality-level index that is developed based on a 2005 survey that provides information on various aspects of local land use control environments, including the general characteristics of the regulatory process, statutory limits on development, density restrictions, open space requirements, infrastructure cost sharing and approval delay. It is supplemented by information on local ballot initiatives and state involvement in land use controls. The WRLURI itself is the first factor from a factor analysis of eleven sub-indices; a higher value indicates a more restrictive environment.

The data on geographic land scarcity is from Saiz (2010), who estimates the proportion of land unsuitable for housing development because of water bodies, wetlands and slopes within 50-kilometer radii from metropolitan central cities. The estimates are available for 95 major metropolitan areas. For our city-level analysis, we assign to each city the value associated with the metropolitan area where it is

[5]The *Wall Street Journal on line* (February 14, 2007) tested the accuracy of Zillow estimates with a sample of 1,000 homes in seven states, and found a median margin of error of 7.8 percent and an equal split between overestimates and underestimates. Mian and Sufi (2009) used Zillow data aggregated at the zip code level for their robustness checks. They find from 2,248 zip codes that house price changes from the Zillow index and the Fiserv Case Shiller Weiss index have a correlation coefficient of 0.91.

located.

The mortgage rejection rate in 1996 is from the Loan Application Register (LAR) of the Home Mortgage Disclosure Act (HMDA), which covers a large majority of mortgage loans sold in the US (Avery et al., 2007). We excluded refinancing loan applications from the calculation since such applications may not indicate pent-up demand for housing.[6] The percentage of high-cost loans, defined as mortgage loans sold between 2004 and 2006 that had a rate spread 3 percentage points above the Treasury security of comparable maturity, was compiled by the US Department of Housing and Urban Development (HUD) for forecasting local foreclosure risks.[7] There is a high correlation between the two subprime variables (the correlation coefficient > 0.7).

Among the control variables, the changes in employment and median household income are from the Local Area Unemployment Statistics program of the Bureau of Labor Statistics and the USA Countries data files, respectively. We use the information at the county level because this gives us a better sample coverage, and because the income variable is available only at the county level. For the boom regression, we control for both employment and income growth. For the bust regression, we use only the employment growth, because the income information for years after 2007 is not yet available at the source. Other control variables are from the 2000 Census at the city level.

The use of multiple data sources imposes a multi-level filtering process: Zil-

[6]There is a counter-argument against the exclusion based on measurement, because the outcomes of refinancing applications (denial or approval) in 1996 provide valid information about local credit constraints. But the exclusion has a negligible impact on the results to be reported in this paper (a side-by-side comparison is presented in Table A.3 of an online appendix at www.ualberta.ca/∼haifang/AppHTJUE.pdf.

[7]The data is also derived from the HMDA database. The rate spread information became available only starting from 2004. For more information, please refer to "Neighborhood Stabilization Program Data, Methodology and Data Dictionary for HUD Provided Data." Both the rejection rates and the share of high-cost loans are aggregated to the city level from census tract averages with resident population as weights.

low's data does not include 15 states that are less densely populated; the regulation data is from a survey with a 38 percent response rate (Gyourko et al., 2008); the geographic information in Saiz (2010) covers only the largest 95 metropolitan areas. After the filtering, the final usable sample consists of 327 cities from 29 states.[8] It covers areas where 47 million Americans resided as of the 2000 Census, which is 28 percent of our targeted population universe (urban population living in cities with at least 10,000 residents).

To separate the housing cycle into the boom and bust phases, we examine the average house prices in the sample. The peak is June 2006. We thus define the price boom as the percentage change in house prices from January 2000 to June 2006, and the price bust as the change from June 2006 to July 2009.

Table 1 provides summary statistics. The average increase of real housing prices, adjusted with the Consumer Price Index excluding shelters, is 56.54 percent. The average price bust is 24.94 percent. The index of housing regulation has a mean of 0.14 and a standard deviation of 0.87, indicating that the cities in our sample are more regulated and more homogeneous than the nation as a whole, because the index, namely WRLURI, is standardized nationally to have a mean of 0 and a standard deviation of 1. On average, the cities in the sample have 30.76 percent of land that is not suitable for housing development, and had 26.41 percent of their mortgage loan applications rejected in 1996. The standard deviation of the rejection rate is 12.3 percent, indicating large variations in the initial credit conditions. Among the mortgage loans that were originated between 2004 and 2006, 26.13 percent were classified as high-cost loans.

Table 2 tabulates the changes in house prices by the regulation index, the

[8] They are Alabama, Arkansas, Arizona, California, Colorado, Connecticut, Delaware, Florida, Georgia, Illinois, Kentucky, Massachusetts, Maryland, Michigan, Minnesota, North Carolina, Nebraska, New Jersey, Nevada, New York, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, Virginia, Washington and Wisconsin.

share of undevelopable land, the mortgage rejection rate and the share of high-cost mortgages. It shows that cities that are more supply restricted in the housing market experienced greater booms and busts in housing prices. The same is true for cities that had higher mortgage rejection rates in 1996, and for those that had greater shares of high-cost mortgages from 2004 to 2006.

4 Regression Results

Table 3 presents the regression results. Each column in the table corresponds to one estimation. The variables shown on the top row are dependent variables. Due to the presence of interactive terms, we removed the means from right-hand-side variables before interacting them with one another. This way we can interpret the coefficients on non-interactive terms as marginal effects at sample means.

The estimates show that more restrictive geographic or regulatory constraints on housing supply are associated with greater booms and busts in house prices. If the regulation score increases by one standard deviation (in its nationwide scale) while all other variables remain at their sample averages, the estimates in columns (1) and (3) suggest that the price boom will be 5.64 percentage points greater and the bust 4.55 percentage points deeper. If the share of undevelopable land rises by one standard deviation (19.38 percent), the price boom will be 9.3 percentage points greater and the bust 5.04 percentage points deeper. All the relevant estimates are statistically significant at conventional levels. Similar observations are made in columns (2) and (4) that use the share of high-cost mortgages in places of the 1996 rejection rate.

Local dependence on subprime mortgage credit, indicated by the 1996 mortgage rejection rate, is associated with greater swings in house prices. Furthermore, the subprime dependence's boom-and-bust consequences are more severe in cities

that face greater supply constraints in the housing market. In cities that have average supply conditions, a one standard deviation (12.3 percent) increase in the rejection rate amplified the boom by 1.35 percentage points and deepens the bust by 5.29 percentage points. In cities where the regulation index is one standard deviation above the average, the impacts from the same increase in the rejection rate are 7.5 percentage points for the boom and -9.1 percentage points for the bust. In cities where the share of undevelopable land is one standard deviation (19.38 percent) above the average, the impacts are 10.89 percentage points for the boom and -6.96 percentage points for the bust. Quantitatively similar observations are made using the share of high-cost mortgages as the alternative to measure subprime dependence.[9]

5 Robustness checks and further discussions

We first address an endogeneity concern. We recognize that, although more stringent regulations in housing supply is associated with greater price booms and busts, the causation between regulations and price movements can run in both directions. Cities can adjust their residential land use policies as a response to changes in house prices. The survey behind the regulatory index, namely WRLURI, was conducted in 2005. The regulatory environment at the time might have been influenced by prior gains in house prices. For robustness, we estimate the models using two sub-indices of the WRLURI at the state level: the state political involvement index (SPII) and the state court involvement index (SCII). The SPII measures state involvement in affecting residential building activities and/or growth management, as well as

[9]Specifically, in cities with average supply conditions, a one standard deviation (11.51%) increase in the share of high-cost mortgages raises the price boom by 4.14 percentage points and deepens the bust by 4.37 percentage points. In cities where the regulation index is one standard deviation higher, the impacts are 7.60 percentage points and -8.17 percentage points, respectively. In cities where the share of undevelopable land is one standard deviation higher, the impacts are 13.07 percentage points and -5.49 percentage points, respectively.

the extent to which a state's executive and legislative branches promote land use restrictions (Gyourko et al., 2008). The SCII, developed by Foster and Summers (2005), measures the tendency of the judicial system of a state to uphold municipal land use regulations and thus its deference to municipal land controls. The state-level indices are likely to be exogenous to city-level movements in house prices, especially in the case of the SCII, since the courts are unlikely to judge based on movements in house prices.

Table 4 repeats the regressions in Table 3 while replacing the city-level index with the simple average of SPII and SCII.[10] Treating the two indices alternatively gives us qualitatively consistent and quantitatively comparable estimates; combining them together improves the estimates' precision. The combined index is labeled as the "state political & court involvement index." The regression results in the new table are similar to those reported in Table 3: the state-level index is correlated with the greater booms and greater busts; the estimated effects are statistically significant even after cluster-correcting the standard errors for intra-state correlations. The regulation index's interactions with the 1996 mortgage rejection rate have the same signs as in Table 3. The interactive effect is not precisely estimated in the boom equation, but is comparable in size with the interactive effect in the bust equation, which is statistically significant. The comparable size indicates that the amplification effect from supply restrictions in the boom was completely reversed in the bust. Similar observations are made from the regressions that use the share of high-cost mortgage in places of the 1996 rejection rate.

An online appendix reports other robustness tests. In one of them, we interact the variables of subprime dependence (the 1996 rejection rate or the share of high-cost loans) with all the city-level census variables in 2000; the purpose is to see if

[10]The two state-level indices have comparable scales. The SPII has a range from -1.4 to 2.4 in our sample. The SCII has a three-point scale from 1 to 3.

the interactive terms between the credit variables and the two supply constraints retain the signs and significance of their coefficients after the inclusion of those many interactive terms. The answer is yes: all estimates retain their signs; most (6 out of 8) retain their significance. In another test, we include MSA dummies in all the regressions. Most estimates become small and indistinguishable from zero, suggesting that inter-MSA differences are the driving force behind the findings in Table 3. In the final robustness test, we correct the standard errors by allowing arbitrary correlations of the regression errors within MSAs and, alternatively, within states. Clustering the errors will not affect point estimates, but tends to increase the size of standard errors. Our results are robust to the cluster corrections, regardless the level of clustering.[11]

We now compare our findings to those from Glaeser et al. (2008). We find that cities that have a smaller share of developable land experienced greater declines in house prices from 2006 to 2009. In contrast, Glaeser et al. (2008) found that there was "little correlation between price declines during the bust [from 1989 to 1996] and the degree of elasticity [measured by the share of developable land]" (p. 213). Further examination shows that the difference in the two sets of findings is due to the sample periods.

We first conduct a comparison between the two housing busts in an identical regression model with the same price index and the same set of geographic areas, leaving the sample periods as the only source of differences. Because Zillow's price

[11] See Tables A.4 and A.5 of the online appendix. In our main specification, every estimated effect related to the regulation index, main or interactive with the 1996 mortgage rejection rate, remains significant at the 5 percent confidence level or better, whether we cluster the residuals at the state level or at the MSA level (in columns 1 and 3 of tables A.4 and A.5). The same is true for three of the four estimated effects related to the share of undevelopable land. The only estimate that loses statistical significance is the land share*rejection interactive effect during the bust. We emphasize that this interactive effect still has the "right" sign, while the main effects of the land variable, measured at the sample mean, always remain significant ($p < 0.05$) and indicate that limited geography is linked to greater price booms and busts.

index is not available for years before 2000, we have to switch to the FHFA House Price Index. The index is available only at the MSA level, so the analysis has to switch to the MSA level as well. In the years between the two busts, the US Office of Management and Budget changed the area composition of MSAs. This creates difficulties when making comparisons over time, because the geographic land variable from Saiz (2010) is measured for MSAs defined under the old federal standard, while the FHFA index now uses the new standard. To bypass the problem, our analysis only includes areas that were largely unaffected by the change, which we define as areas where more than 90 percent of the residents belonged to the same MSA before and after the change (even if the name of the MSA changed). Our final sample consists of 59 MSAs.

We regress the price changes over the 1989-1996 housing bust on the share of undevelopable land, the employment growth and a constant. The coefficient on the land variable is -0.06 with a standard error of 0.08. From an identical regression for the 2006-2009 bust, the coefficient rises to -0.21 with a standard error of 0.05. Since the sample periods are the only source of differences, the two estimates present a stark contrast between the two busts.

In addition, we apply the model specification used by Glaeser et al. (2008) for their 1989-1996 data to our 2006-2009 data, using as covariates the population share of college graduates, initial personal income, income growth, mean January temperature and mean annual precipitation. The coefficient of the land variable is little changed, becoming -0.22 with a standard error of 0.08. In light of the evidence, we conclude that the different sample periods are the source of difference between our findings and those reported in Glaeser et al. (2008).[12]

[12] Although the analysis above uses MSAs with little change in area definitions for maximum comparability over time, very similar observations are made in a larger sample of MSAs including areas have gone thought division or consolidation, but for which the land variable can be reconstructed across definitions based on geographic correspondence and population weights. The online

It is more difficult to identify the economic forces responsible for the differences between the two busts. Our efforts to do so produce inconclusive results. We first examine new construction in the booms preceding the busts. Glaeser et al. (2008) show that during the course of a housing bubble, inelastic housing supply, combined with adaptive expectation, can theoretically lead to more construction in addition to a greater jump in house prices, a combination that will certainly lead to a greater bust in house prices after the bubble. Has this theoretical possibility played out to a greater extent in the 2000-2006 boom than in the 1982-1989 boom? Simple correlation statistics do not support this hypothesis. In our sample of MSAs, the correlation between the share of undevelopable land and new construction (number of housing permits normalized by the initial housing stock) is more negative in the recent boom than it was in the earlier one. For an alternative explanation, we test whether land scarcity has forced new construction to peripheries farther away from metro centers during the boom, and then excessive construction in those fringe areas led to a greater bust.[13] We use the increases in average commute time to work, obtained from the censuses and the American Community surveys, to measure the expansion of MSAs.[14] We did not find significant correlations between the changes in commute time and the land variable in either one of the two booms.

One possible reason for the difference is the greater magnitude of the recent housing price movements. More importantly, however, the housing boom preceding the 2006-2009 bust was not just bigger, but also more dependent on land availability. In our sample of MSAs, the variable of land availability alone explains 40 percent of the cross-sectional difference in price increases from 2000 to 2006; in contrast, it

appendix report those regressions in Tables A.6 and A.7.

[13] We thank an anonymous referee for the suggestion.

[14] For the 1982-1989 boom, we compute the increase in commute time as the difference in average commute time between the 1980 and the 1990 censuses (data source: Missouri Census Data Centre). For the 2000-2006 housing boom, we take the difference between the mean travel time to work reported in the 2005-2007 American Community Surveys and that reported in the 1999-2001 surveys.

explains a mere 12 percent of the variation in the 1982-1989 boom. Glaeser et al. (2008) reported similar findings (see tables 3 and 7 of the cited paper). Why has land become so much more important during the recent price build-up? One explanation is the elevated importance of land cost as a share of home values, which Davis and Palumbo (2008) found from a sample of large MSAs to have risen from 32 percent in 1984 to 40 percent in 1998 and 51 percent in 2004. The greater importance of land, as Davis and Palumbo (2008) hypothesized, implies that "cycles in land prices will shape the contour of home values to a greater extent than they have in the past" (p. 367). It is thus not surprising that land constraints became more prominent in the 2000-2006 price boom. But the greater price increases might have also exposed inelastic areas to greater downward pressures in the bust.

6 Conclusion

Using data from over 300 US cities, we examine how residential land use regulation, geographic land scarcity and subprime mortgage credit expansion were related to the amplitude of the housing price cycle between January 2000 and July 2009. We find that cities that are more regulated or have less developable land experienced greater price gains between January 2000 and June 2006, and greater price declines between June 2006 and July 2009. Furthermore, the supply constraints in the housing market amplified the boom-and-bust consequences of the subprime expansion in the mortgage market: an increase in local borrowers' reliance on subprime mortgages, indicated by the mortgage rejection rate before the subprime expansion, was associated with greater price booms and busts in cities that are more supply restricted.

Our findings expand the body of evidence documented in the existing literature. From an earlier housing cycle, Glaeser et al. (2008) found little correlation

between land availability and price corrections in the 1989-1996 bust. In contrast, we find that land supply constraints amplified the decline in house prices from 2006 to 2009. The greater magnitude of the more recent bust, as well as the elevated share of land cost in home values (Davis and Palumbo, 2008), might have made it easier to detect the relationship between the factors of land supply and the movements in house prices.

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Table 1: Summary statistics for key variables

Variable	Mean	Standard deviation	Min	Max	Obs.
Housing price change between Jan. 2000 and June 2006 (%)	56.54	57.93	-49.09	454.89	327
Housing price change between June 2006 and July 2009 (%)	-24.94	16.52	-65.25	30.88	327
Wharton Residential Land Use Regulatory Index	0.14	0.87	-1.94	3.46	327
Proportion of undevelopable area in Saiz (2008) (%)	30.76	19.38	1.04	79.64	327
Proportion of mortgage applications denied in 1996 (%)	26.41	12.30	4.77	65.13	327
Proportion of high-interest loans between 2004 and 2006 (%)	26.13	11.51	5.39	70.32	327

Table 2: Housing price boom and bust in subsamples

Subsamples with	Average price gain 2000-2006	Average price loss 2006-2009	Obs.
more stringent regulation	65.95	-29.19	164
	(4.25)	(1.15)	
less stringent regulation	47.07	-20.65	163
	(4.70)	(1.34)	
more undevelopable area	79.64	-28.58	166
	(4.30)	(1.17)	
less undevelopable area	32.72	-21.18	161
	(3.98)	(1.35)	
more mortgage rejections	73.14	-26.42	164
in 1996	(4.67)	(1.46)	
fewer mortgage rejections	39.84	-23.44	163
in 1996	(3.99)	(1.08)	
more high-interest loans	69.95	-26.10	164
between 2004 and 2006	(5.32)	(1.53)	
fewer high-interest loans	43.04	-23.76	163
between 2004 and 2006	(3.25)	(0.99)	

Note: The numbers in the parentheses are the standard errors of means.

Table 3: Main results

	$\%\Delta P_{2000-06}$	$\%\Delta P_{2000-06}$	$\%\Delta P_{2006-09}$	$\%\Delta P_{2006-09}$
Variables	(1)	(2)	(3)	(4)
regulation	5.64	4.98	-4.55	-4.66
	(2.08)***	(2.10)**	(0.92)***	(0.9)***
undevelopable land (%)	0.48	0.5	-.26	-.29
	(0.13)***	(0.12)***	(0.04)***	(0.04)***
rejection (%)	0.11		-.43	
	(0.24)		(0.1)***	
regulation*rejection	0.5		-.31	
	(0.15)***		(0.08)***	
undevelopable land*rejection	0.04		-.007	
	(0.009)***		(0.004)**	
high-interest loans (%)		0.36		-.38
		(0.24)		(0.1)***
regulation*high-interest loans		0.3		-.33
		(0.16)*		(0.07)***
undevelopable land*high-interest loans		0.04		-.005
		(0.008)***		(0.003)*
Δ employment 2000-2006 (%)	1.08	0.99		
	(0.36)***	(0.35)***		
Δ HH income 2000-2006 (%)	3.85	4.15		
	(0.36)***	(0.38)***		
Δ employment 2006-2009 (%)			1.28	1.02
			(0.22)***	(0.23)***
population density in 2000	0.67	0.58	-.24	-.24
	(0.47)	(0.46)	(0.14)*	(0.14)*
population in 2000	-.007	-.005	0.001	0.0008
	(0.003)**	(0.003)*	(0.0007)**	(0.0007)
mean HH income in 2000	0.03	0.05	-.12	-.11
	(0.08)	(0.09)	(0.04)***	(0.04)***
share of urban pop. in 2000 (%)	0.46	0.42	-.11	-.12
	(0.5)	(0.5)	(0.31)	(0.29)
unemployment rate in 2000(%)	2.64	1.95	0.31	0.11
	(1.30)**	(1.21)	(0.4)	(0.38)
vacancy rate in 2000 (%)	0.006	-.55	-.34	-.16
	(0.78)	(0.7)	(0.26)	(0.3)
Const.	56.89	57.93	-25.32	-25.81
	(2.01)***	(2.10)***	(0.79)***	(0.82)***
Obs.	327	327	327	327
R^2	0.62	0.63	0.33	0.32
F statistic	79.53	68.52	12.68	14.01

Notes: (1) The variables shown on the top row are dependent variables, measured in percentages. (2) The numbers in the parentheses are heterskedasticity-robust standard errors. (3) *, **, and *** indicate statistical significance at the 10%, 5% and 1% levels.

Table 4: Robustness checks with state-level indices

	$\%\Delta P_{2000-06}$	$\%\Delta P_{2000-06}$	$\%\Delta P_{2006-09}$	$\%\Delta P_{2006-09}$
	(1)	(2)	(3)	(4)
state political & court involvement index	15.98 (6.00)***	16.51 (5.86)***	-10.26 (2.85)***	-10.49 (3.46)***
undevelopable land (%)	0.41 (0.25)	0.43 (0.16)***	-.19 (0.1)*	-.22 (0.08)***
rejection (%)	-.07 (0.33)		-.27 (0.16)*	
state political & court involvement*rejection	0.51 (0.43)		-.53 (0.22)**	
undevelopable land*rejection	0.04 (0.01)***		-.005 (0.006)	
high-interest loans		0.37 (0.28)		-.37 (0.1)***
state political & court involvement*high-interest loans		0.43 (0.38)		-.43 (0.24)*
undevelopable land*high-interest loans		0.04 (0.005)***		-.008 (0.005)*
Δ employment 2000-2006 (%)	0.98 (0.38)**	0.78 (0.39)**		
Δ HH income 2000-2006 (%)	3.49 (0.49)***	3.79 (0.55)***		
Δ employment 2006-2009 (%)			1.37 (0.33)***	1.13 (0.37)***
census profile in 2000	included	included	included	included
Const.	55.09 (4.03)***	57.19 (4.18)***	-23.77 (1.83)***	-24.98 (1.92)***
Obs.	327	327	327	327
R^2	0.64	0.65	0.42	0.42

Notes: (1) The variables shown on the top row are dependent variables, measured in percentages. (2) The numbers in the parentheses are heterskedasticity-robust standard errors cluster-corrected for intra-state correlations. (3) *, **, and *** indicate statistical significance at the 10%, 5% and 1% levels. (4) The census profile variables are from the 2000 Census and include the following: population size, population density, the level of average household income, the share of urban population, the unemployment rate and the proportion of vacant housing units.

Online Appendix to "Residential Land Use Regulation and the US Housing Price Cycle Between 2000 and 2009"

August 2011

Table A.1: Robustness checks: including extra interactive terms for the subprime variables

	$\%\Delta P_{2000-06}$	$\%\Delta P_{2000-06}$	$\%\Delta P_{2006-09}$	$\%\Delta P_{2006-09}$
Variables	(1)	(2)	(3)	(4)
regulation	5.71	4.75	-4.09	-3.77
	(2.17)***	(2.15)**	(0.94)***	(0.9)***
undevelopable land (%)	0.41	0.47	-.24	-.27
	(0.12)***	(0.11)***	(0.04)***	(0.04)***
rejection (%)	0.22		-.54	
	(0.22)		(0.11)***	
regulation*rejection	0.48		-.25	
	(0.14)***		(0.08)***	
undevelopable land*rejection	0.04		-.008	
	(0.008)***		(0.003)**	
high interest loans (%)		0.71		-.70
		(0.24)***		(0.13)***
regulation*high interest loans		0.15		-.20
		(0.16)		(0.08)***
undevelopable land*high interest loans		0.04		-.003
		(0.008)***		(0.003)
Δ employment 2000-2006 (%)	1.03	0.92		
	(0.32)***	(0.34)***		
Δ HH income 2000-2006 (%)	3.85	4.16		
	(0.35)***	(0.39)***		
Δ employment 2006-2009 (%)			1.46	1.15
			(0.22)***	(0.22)***
census profile in 2000	included	included	included	included
census profile in 2000*rejection	included		included	
census profile in 2000*high interest loans		included		included
Const.	60.46	62.53	-27.52	-29.57
	(2.86)***	(2.89)***	(1.03)***	(1.20)***
Obs.	327	327	327	327
R^2	0.64	0.64	0.37	0.37
F statistic	71.44	50.45	11.38	12.8

Notes: (1) The variables shown on the top row are dependent variables, measured in percentages. (2) The numbers in the parentheses are heterskedasticity-robust standard errors. (3) *, **, and *** indicate statistical significance at the 10%, 5% and 1% levels.

Table A.2: Robustness checks: including MSA fixed effects

	$\%\Delta P_{2000-06}$	$\%\Delta P_{2000-06}$	$\%\Delta P_{2006-09}$	$\%\Delta P_{2006-09}$
Variables	(1)	(2)	(3)	(4)
regulation	-3.19	-3.12	-.25	-.26
	(3.47)	(3.42)	(0.58)	(0.57)
rejection (%)	-.12		-.06	
	(0.17)		(0.06)	
regulation*rejection	-.006		0.004	
	(0.16)		(0.05)	
undevelopable land*rejection	0.01		-.005	
	(0.01)		(0.003)**	
high interest loans (%)		-.04		-.14
		(0.19)		(0.07)**
regulation*high interest loans		0.05		-.01
		(0.19)		(0.06)
undevelopable land*high interest loans		0.02		-.008
		(0.01)		(0.003)***
Δ employment 2000-2006 (%)	-.14	-.15		
	(0.27)	(0.26)		
Δ HH income 2000-2006 (%)	-.66	-.68		
	(0.96)	(0.92)		
Δ employment 2006-2009 (%)			-.53	-.53
			(0.38)	(0.36)
census profile in 2000	included	included	included	included
MSA fixed effects	included	included	included	included
Const.	56.43	56.93	-24.87	-25.11
	(1.53)***	(1.38)***	(0.36)***	(0.36)***
Obs.	327	327	327	327
R^2	0.81	0.81	0.88	0.89
F statistic	1.8	2.21	1.77	2.26

Notes: (1) The variables shown on the top row are dependent variables, measured in percentages. (2) The numbers in the parentheses are heterskedasticity-robust standard errors. (3) *, **, and *** indicate statistical significance at the 10%, 5% and 1% levels.

Table A.3: Compare the alternative 1996 rejection rates in the city-level analysis

	The 1996 rejection rate excluding refinancing-loan applications		The 1996 rejection rate based on all mortgage applications	
	$\%\Delta P_{2000-06}$	$\%\Delta P_{2006-09}$	$\%\Delta P_{2000-06}$	$\%\Delta P_{2006-09}$
Variables	(1)	(2)	(3)	(4)
regulation	5.64	-4.55	5.70	-4.39
	(2.08)***	(0.92)***	(2.08)***	(0.93)***
undevelopable land (%)	0.48	-.26	0.47	-.25
	(0.13)***	(0.04)***	(0.13)***	(0.04)***
rejection (%)	0.11	-.43	0.18	-.50
	(0.24)	(0.1)***	(0.3)	(0.11)***
regulation*rejection	0.5	-.31	0.56	-.35
	(0.15)***	(0.08)***	(0.17)***	(0.09)***
undevelopable land*rejection	0.04	-.007	0.05	-.008
	(0.009)***	(0.004)**	(0.01)***	(0.004)**
Δ employment 2000-2006 (%)	1.08		1.06	
	(0.36)***		(0.36)***	
Δ HH income 2000-2006 (%)	3.85		3.78	
	(0.36)***		(0.35)***	
Δ employment 2006-2009 (%)		1.28		1.37
		(0.22)***		(0.22)***
population density in 2000	0.67	-.24	0.78	-.22
	(0.47)	(0.14)*	(0.47)*	(0.14)
population in 2000	-.007	0.001	-.007	0.001
	(0.003)**	(0.0007)**	(0.002)***	(0.0008)*
mean household income in 2000	0.03	-.12	0.04	-.12
	(0.08)	(0.04)***	(0.08)	(0.04)***
share of urban pop. in 2000 (%)	0.46	-.11	0.47	-.14
	(0.5)	(0.31)	(0.49)	(0.31)
unemployment rate in 2000 (%)	2.64	0.31	2.40	0.41
	(1.30)**	(0.4)	(1.33)*	(0.38)
vacancy rate in 2000 (%)	0.006	-.34	0.14	-.38
	(0.78)	(0.26)	(0.77)	(0.26)
Obs.	327	327	327	327
R^2	0.62	0.33	0.63	0.33

Notes: (1) The variables shown on top of the column number are dependent variables, measured in percentages. (2) The numbers in the parentheses are heterskedasticity-robust standard errors. (3) *, **, and *** indicate statistical significance at the 10%, 5% and 1% levels. (4) The population size is in thousands. The population density is thousand per square mile. The mean household income is in thousand dollars.

Table A.4: Main results - with cluster-corrected standard errors by MSAs

	$\%\Delta P_{2000-06}$	$\%\Delta P_{2000-06}$	$\%\Delta P_{2006-09}$	$\%\Delta P_{2006-09}$
	(1)	(2)	(3)	(4)
regulation	5.64	4.98	-4.55	-4.66
	(2.57)**	(2.62)*	(1.43)***	(1.47)***
undevelopable land (%)	0.48	0.5	-.26	-.29
	(0.19)**	(0.15)***	(0.08)***	(0.08)***
rejection (%)	0.11		-.43	
	(0.33)		(0.15)***	
regulation*rejection	0.5		-.31	
	(0.17)***		(0.11)***	
undevelopable land*rejection	0.04		-.007	
	(0.01)***		(0.006)	
high interest loans		0.36		-.38
		(0.32)		(0.12)***
regulation*high interest loans		0.3		-.33
		(0.16)*		(0.11)***
undevelopable land*high interest loans		0.04		-.005
		(0.009)***		(0.005)
Δ employment 2000-2006 (%)	1.08	0.99		
	(0.39)***	(0.39)**		
Δ HH income 2000-2006 (%)	3.85	4.15		
	(0.51)***	(0.58)***		
Δ employment 2006-2009 (%)			1.28	1.02
			(0.42)***	(0.5)**
population density in 2000	0.67	0.58	-.24	-.24
	(0.5)	(0.46)	(0.18)	(0.17)
population in 2000	-.007	-.005	0.001	0.0008
	(0.002)***	(0.003)*	(0.0007)**	(0.0006)
mean HH income in 2000	0.03	0.05	-.12	-.11
	(0.09)	(0.11)	(0.05)**	(0.05)**
share of urban pop. in 2000 (%)	0.46	0.42	-.11	-.12
	(0.53)	(0.53)	(0.27)	(0.26)
unemployment rate in 2000(%)	2.64	1.95	0.31	0.11
	(1.33)**	(1.27)	(0.57)	(0.6)
vacancy rate in 2000 (%)	0.006	-.55	-.34	-.16
	(0.92)	(0.89)	(0.34)	(0.4)
Const.	56.89	57.93	-25.32	-25.81
	(2.96)***	(3.19)***	(1.62)***	(1.79)***
Obs.	327	327	327	327
R^2	0.62	0.63	0.33	0.32

Notes: Notes: (1) The variables shown on the top row are dependent variables, measured in percentages. (2) The numbers in the parentheses are heterskedasticity-robust standard errors cluster-corrected for intra-MSA correlations. (3) *, **, and *** indicate statistical significance at the 10%, 5% and 1% levels. (4) The census profile variables are from the 2000 census and include the following: population size, population density, the level of average household income, the share of urban population, the unemployment rate and the proportion of vacant housing units.

Table A.5: Main results - with cluster-corrected standard errors by states

	$\%\Delta P_{2000-06}$	$\%\Delta P_{2000-06}$	$\%\Delta P_{2006-09}$	$\%\Delta P_{2006-09}$
	(1)	(2)	(3)	(4)
regulation	5.64	4.98	-4.55	-4.66
	(2.67)**	(2.43)**	(1.21)***	(1.29)***
undevelopable land (%)	0.48	0.5	-.26	-.29
	(0.2)**	(0.14)***	(0.08)***	(0.08)***
rejection (%)	0.11		-.43	
	(0.36)		(0.15)***	
regulation*rejection	0.5		-.31	
	(0.21)**		(0.13)**	
undevelopable land*rejection	0.04		-.007	
	(0.01)***		(0.006)	
high interest loans		0.36		-.38
		(0.31)		(0.12)***
regulation*high interest loans		0.3		-.33
		(0.18)		(0.13)**
undevelopable land*high interest loans		0.04		-.005
		(0.007)***		(0.005)
Δ employment 2000-2006 (%)	1.08	0.99		
	(0.37)***	(0.39)**		
Δ HH income 2000-2006 (%)	3.85	4.15		
	(0.47)***	(0.59)***		
Δ employment 2006-2009 (%)			1.28	1.02
			(0.4)***	(0.49)**
population density in 2000	0.67	0.58	-.24	-.24
	(0.6)	(0.57)	(0.26)	(0.24)
population in 2000	-.007	-.005	0.001	0.0008
	(0.002)***	(0.003)**	(0.0009)	(0.0007)
mean HH income in 2000	0.03	0.05	-.12	-.11
	(0.11)	(0.12)	(0.05)***	(0.05)**
share of urban pop. in 2000 (%)	0.46	0.42	-.11	-.12
	(0.61)	(0.6)	(0.34)	(0.31)
unemployment rate in 2000(%)	2.64	1.95	0.31	0.11
	(1.82)	(1.63)	(0.85)	(0.93)
vacancy rate in 2000 (%)	0.006	-.55	-.34	-.16
	(1.13)	(1.10)	(0.47)	(0.53)
Const.	56.89	57.93	-25.32	-25.81
	(4.25)***	(4.67)***	(2.12)***	(2.50)***
Obs.	327	327	327	327
R^2	0.62	0.63	0.33	0.32

Notes: (1) The variables shown on the top row are dependent variables, measured in percentages. (2) The numbers in the parentheses are heterskedasticity-robust standard errors cluster-corrected for intra-state correlations. (3) *, **, and *** indicate statistical significance at the 10%, 5% and 1% levels. (4) The census profile variables are from the 2000 census and include the following: population size, population density, the level of average household income, the share of urban population, the unemployment rate and the proportion of vacant housing units.

Table A.6: Compare the 2006-2009 bust to the 1989-1996 bust

	Sample of MSAs with little change in area definition		Sample of all MSAs with information on the share of undevelopable land	
	$\%\Delta P_{1989-96}$	$\%\Delta P_{2006-09}$	$\%\Delta P_{1989-96}$	$\%\Delta P_{2006-09}$
undevelopable land (%)	-.06	-.21	-.04	-.24
	(0.08)	(0.05)***	(0.09)	(0.04)***
Δ employment 1990-1996 (%)	0.59		0.58	
	(0.21)***		(0.16)***	
Δ employment 2006-2009 (%)		2.19		1.96
		(0.4)***		(0.26)***
Obs.	59	59	105	105
R^2	0.16	0.62	0.17	0.47

Notes: (1) The variables shown on the top row are dependent variables, measured in percentages. (2) The numbers in the parentheses are heterskedasticity-robust standard errors. (3) *, **, and *** indicate statistical significance at the 10%, 5% and 1% levels. (4) The data currently available on the BLS State and Area Employment, Hours and Earnings (SM) program does not go back before 1990. So the change in employment for the earlier episode is defined as the change from 1990 to 1996, instead of from 1989 to 1996. (5) The sample of MSAs with little changes in area definition are the MSAs where more than 90% of residents belong to the same MSA before and after the change in the federal statistical standard (even if the name of the MSA changed). The bigger sample consists all MSAs for which the share of undevelopable land can be reconstructed from the old definition to the new definition. It therefore allows division and consolidations. For example, if an MSA (or Primary MSA) under the 1999 definition was divided into two MSAs (or Metropolitan Divisions) in the update, both will be assigned the same elasticity value that was constructed for the old MSA. If parts of different MSAs were combined to form a new MSA, a weighted average will be adopted for the new area.

Table A.7: Apply the model specification in Glaeser et al. (2008) to the data from 2006 to 2009

	Sample of MSAs with little change in area definition	Sample of all MSAs with information on the share of undevelopable land
	$\%\Delta P_{2006-09}$	$\%\Delta P_{2006-09}$
undevelopable land (%)	-.22	-.16
	(0.08)***	(0.08)**
real per person income; 2000	-.0006	-.0005
	(0.0004)	(0.0004)
real income growth (%); 2006-09	1.42	1.08
	(0.44)***	(0.3)***
mean annual precipitation	0.35	0.45
	(0.1)***	(0.09)***
mean January temperature	-.31	-.35
	(0.12)***	(0.11)***
percent college graduate; 2000	1.45	0.7
	(0.5)***	(0.34)**
Obs.	59	106
R^2	0.69	0.56

Notes: (1) The variables shown on the top row are dependent variables, measured in percentages. (2) The numbers in the parentheses are heterskedasticity-robust standard errors. (3) *, **, and *** indicate statistical significance at the 10%, 5% and 1% levels. (4) See footnote 5 of the preceding table for information about reconstructing the variable of land share between the old and the new area definitions. (6) The mean January temperature is in the unit of Fahrenheit degrees. The mean annual precipitation is in the unit of inches. Both are from the list of "Long-term monthly averages/normals for over 270 U.S. cities" available online at the National Climate Data Center (NCDC). For metropolitan areas that does not have a good match to the cities on the list, we use the information of close-by cities.