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Where are the speculative bubbles in US housing markets? ☆

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Abstract

In the first half of this decade, US house prices experienced significant real rates of appreciation. The dramatic increase in house prices led some economists to conclude that there was a speculative bubble in the US housing market.

This paper explores how much of the recent appreciation in US house prices was attributable to the fundamental economic determinants of house prices. On the demand side, we note that the rate of homeownership in the US increased from 66.8% in 1999 to 69% in the fourth quarter of 2005. http://www.census.gov/hhes/www/housing/hvs/historic/histt14.html, accessed 10/17/2007. Each percentage point increase in the homeownership rate increases the demand for owner-occupied housing by about one million units. On the supply side, land prices and housing construction costs increased substantially in real terms over this period.

The national average increase in house prices conceals significant spatial variation in appreciation rates. According to OFHEO, house prices in some California cities increased by more than fifteen percent per year during this period while house prices in Texas cities increased four percent per year. The increase in aggregate housing demand had different effects on metropolitan area house prices because housing market supply elasticities vary spatially. We estimate housing supply elasticities for 133 metropolitan areas and conclude that although areas on the East Coast and in California had large observed price increases, they owe much of their house price increases to inelastic supplies of owner-occupied housing.

JEL classification: R00

Keywords: Housing price bubbles; Housing prices; Bubbles

1. Introduction

From 2000 through 2005 house prices in the United States increased by 8.9% per year nominally or 6.5% per year in real terms. This increase in national house prices followed a decade in which house prices stayed roughly constant in real terms (Fig. 1). The 2000–2005 real house price appreciation prompted numerous

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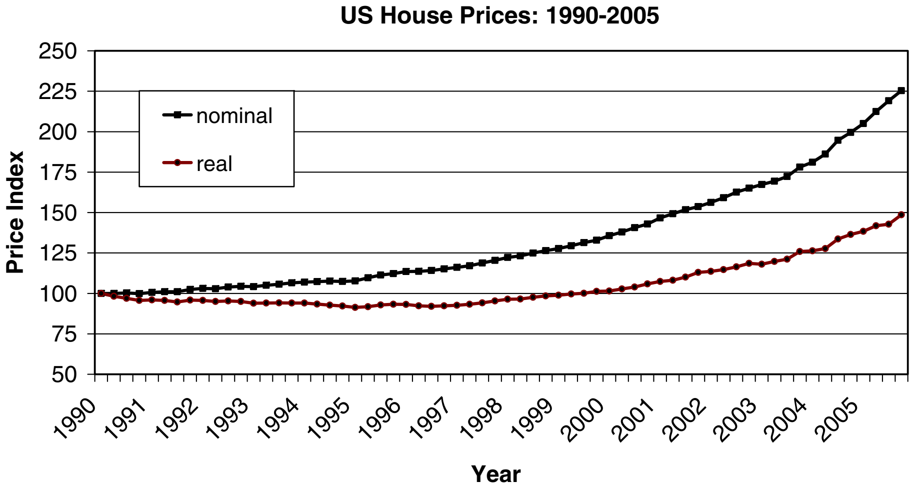

Fig. 1. Source: OFHEO.

economists and the national media to conclude that there has been a speculative bubble in the US housing market. Such proclamations ignore the significant changes in the fundamental economic determinants of house prices that occurred over this period. On the supply side, the US Department of Agriculture reports that the national average price of agricultural land increased 9.7% per year (nominally) over the 2000–2005 period. In addition, RS Means reports that construction costs increased about 5% per year over this period, over twice the rate of inflation.

When the supply price of a good or service increases, consumers typically purchase less, but the 2000–2005 interval was anything but typical for the US housing market. With supply prices increasing in real terms, the aggregate demand for owner-occupied housing also increased dramatically and US housing consumers purchased more, not less, owner-occupied housing. The increase in housing demand can be attributed to (at least) three causes: (1) an increased rate of homeownership, from 66.8% in 1999 to 69% in the fourth quarter of 2005; (2) household decisions to allocate larger portions of their wealth to real estate in general, and to owner-occupied housing in particular; and (3) speculation in continued real house price appreciation. All three contributed to higher house prices.

Relative to population growth, the US experienced rapid growth in both numbers of households and numbers of owner-occupied households from 2000 through 2005. The resident population of the United States rose from 282,403,000 in July 2000 to 296,639,000 in July 2005.[1] There were 104.7 million households in March 2000 and 113.15 million households in March 2005.[2] The difference between the 5.0% increase in population and the 8.1% increase in households is attributable to a decline in average household size.

Rising from under 50% prior to World War II, homeownership rates peaked in 1980 at 65.6%. Falling through the 1980s, largely due to the high real interest rates during that decade, they rose to 65.7% in 1997, 66.8% in 1999, and were estimated at 69% in 2005. Consequently, from 1999 through 2005, the US housing market experienced a 10.3% increase in the number of owner-occupied households. With about 105 million households in the United States in 2000, each percentage point increase in the homeownership rate translates to an additional 1.1 million homeowners. The 2.2 percentage point increase in the homeownership rate increased the demand for owner-occupied housing units by 2.4 million units. This is over and above the increase in aggregate housing demand created by new household formation or by the reduction in average household size. The increase in home-ownership can be attributed to: (1) historically low nominal interest rates; (2) shifts in preferences towards homeownership among single-person households; (3) the virtual elimination of the wealth constraint for homeownership in US mortgage markets; (4) continued development of the subprime mortgage market; (5) and further development of the home-equity mortgage market.

[1] http://www.census.gov/prod/2006pubs/07statab/pop.pdf, Table 2, accessed 10/17/2007.
[2] http://www.census.gov/prod/2006pubs/07statab/pop.pdf, Table 57, accessed 10/17/2007.

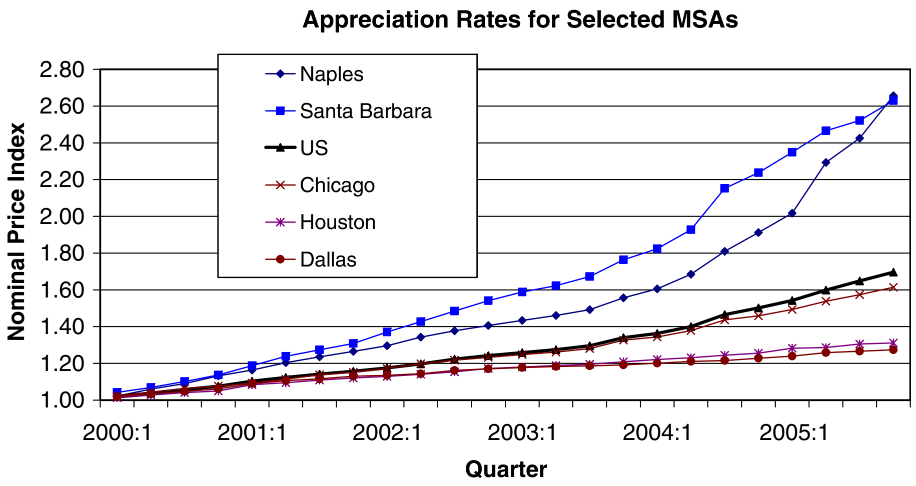

Fig. 2. Source: OFHEO.

American homeowners purchased *more* owner-occupied housing. They built larger homes and purchased more vacation homes. The average size of a single-family detached home built from 1997 through 2005 increased by 232 square feet (8.7%).[3] According to the 1999 National American Housing Survey (AHS), the mean size of a single-family detached home built over the 1997–1999 period was 2663 square feet. The 2005 National AHS shows that the mean size of a single-family detached home built over the 2003–2005 period was 2895 square feet. In addition, Americans purchased 768,000 more vacation homes.

Households also made conscious decisions to include more housing in their portfolios. The percent of household assets held in owner-occupied housing (and in not-for-profit businesses) increased from 23.8% in 2000 to 30% in 2005. One could argue that this increase is attributable to the increase in house prices. However, households' decisions to keep larger shares of their increased wealth in housing were almost certainly related to the downward readjustments in the US equities market in the first few years of this century. The percent of total household wealth in homeowner equity increased from 14.3% in 1999 to 20.5% in 2004.

In sum, there was an increase in the aggregate demand for owner-occupied housing coming from households that had historically rented, while existing homeowners increased their demand for owner-occupied housing by building larger dwellings and by purchasing more vacation homes. The increase in aggregate demand for owner-occupied housing occurred in markets where real supply prices were increasing, and it forced the market price of housing to increase in real terms (in some places more than others). The increase in real rates of house price appreciation led to expectations of further real appreciation. However, expecting some real house price appreciation in supply constrained markets that experience increases in aggregate demand for owner-occupied housing is not irrational (or speculative).

The national average increase in house prices conceals significant spatial variation in appreciation rates. According to OFHEO, house prices in Naples, Florida and some California cities increased by more than fifteen percent per year from 2000 through 2005 while house prices in some Texas cities increased by no more than four percent per year (Fig. 2). The increase in aggregate housing demand had different effects on metropolitan area house prices because housing market supply elasticities vary spatially.

We seek to answer these questions:

- how much real appreciation in house prices was justified by the economic fundamentals of local housing markets?; and
- how much was attributable to speculation?

[3] According to the National AHS, in 1999 there were 115,253,000 housing units in the US. Of these, 2,709,000 (2.35%) were used for vacation purposes. In 2005, there were 124,377,000 housing units in the US. Of these, 3,477,000 were used for vacation purposes.

We approach these questions in two ways. We first examine real house price appreciation using a simple simulation of long-run housing market behavior. The simulation model demonstrates that a key explanation for the observed spatial variation in house price appreciation rates is spatial variation in supply elasticities. Our second, empirical, analysis attempts to estimate supply elasticities for 133 metropolitan areas across the US. We then use the estimated elasticities to estimate how much of each metropolitan area's appreciation can be attributed to economic fundamentals and, by inference, how much is attributable to speculation.

Section 2 reviews the literature we believe relevant for this investigation and Section 3 presents the simulation model. Section 4 presents the empirical model, and Section 5 the data, econometric technique and empirical results. Section 6 uses the estimated supply elasticities as parameters in the simulation model to estimate the increase in house price required to accommodate the observed 10.3% increase in the stock of owner-occupied housing. Our conclusions are in Section 7.

2. Literature review

There are three strands of literature relevant for this investigation:

(1) models of long-run equilibrium in housing markets (Ozanne and Thibodeau, 1983; Goodman, 1988; Capozza and Helsley, 1989, 1990; Mankiw and Weil, 1989; Green and Hendershott, 1996);
(2) models of the short-run dynamics of (house) prices (Stiglitz, 1990; Abraham and Hendershott, 1993, 1996; Capozza et al., 2004; Case and Shiller, 1987, 1989, 2003; Krainer and Wei, 2004; Malpezzi and Wachter, 2005); and
(3) estimates of housing supply elasticities (Muth, 1960; Follain, 1979; Poterba, 1984; DiPasquale and Wheaton, 1994; Malpezzi and Maclennan, 2001; Green et al., 2005; Goodman, 2005a,b, 2006).

Ozanne and Thibodeau (OT, 1983) model spatial variation in house prices using data from the first three waves of the metropolitan American Housing Survey (AHS). OT relate the aggregate demand for owner-occupied housing to the price of housing, household income, the number of owner-occupied households in a metropolitan area, household preferences (measured by the percent of non-elderly single person households and percent minority households), and the components of user cost (expected appreciation, mortgage interest rates, taxes and depreciation). They relate the aggregate supply of owner-occupied housing to the price of housing, the prices of operating inputs, the price of developable land, and the prices of non-land construction inputs (building material costs and construction worker wages). The supply of developable land is a function of urban and agricultural land prices, geographic features that constrain real estate development, and government restrictions on land use. Their reduced form equations explain 60% of the spatial variation in the long-run equilibrium price of owner-occupied housing.

Using a macro model that relates the demand for housing to its demographic determinants, Mankiw and Weil (1989) predicted "real house prices will fall by a total of 47% by the year 2007" (p. 248). While Mankiw and Weil accurately estimated the magnitude of the real price change over the 1990–2007 period, they missed the direction. Green and Hendershott (1996) relate real house prices to numerous socioeconomic household characteristics, in addition to the age of the head of household, and report that the age related decline in housing demand reported by Mankiw and Weil is attributable to household income and education.

Capozza and Helsley (1989) model intermetropolitan area variation in the price of urban land by relating urban land price to four additive components: (1) the present value of agricultural land rent; (2) the cost of converting agricultural land to a non-agricultural use; (3) the value of accessibility; and (4) a premium for expected growth. Their theoretical model demonstrates that the growth premium can account for as much as 59% of the average price of agricultural land.

Case and Shiller's (1987) *New England Economic Review* and 1989 *American Economic Review (AER)* papers demonstrated that house price changes for four metropolitan areas in the US were serially correlated. In the *AER* paper they conclude "A change in real citywide housing prices in a given year tends to predict a change in the same direction, and one-quarter to one-half as large in magnitude, the following year" (p. 135). This finding stimulated research that models short-run price dynamics in housing markets.

The attempts to model short-run house price dynamics also led analysts to investigate speculative bubbles in housing markets. Stiglitz (1990) defines the term speculative bubble: "if the reason that the price is high today is *only* because investors believe that the selling price will be high tomorrow—when 'fundamental' factors do not seem to justify such a high price—then a bubble exists" (p. 13). Case and Shiller (2003) reinforce this definition:

> "We believe that in its widespread use the term refers to a situation in which excessive public expectations of future price increase cause prices to be temporarily elevated...the mere fact of rapid price increases is not in itself conclusive evidence of a bubble. The basic questions that still must be answered are whether expectations of large future price increases are sustaining the market, whether these expectations are salient enough to generate anxieties among potential homebuyers, and whether there is sufficient confidence in such expectations to motivate action" (pp. 299–300).

The identification of speculative bubbles in housing markets requires accurate estimates of both the contemporaneous "fundamental economic value" and housing purchasers' expectations of future appreciation. These tasks challenge housing analysts, particularly since house prices are known to be serially correlated. If house prices are serially correlated (more in some markets than in others), then it is not surprising that they overshoot their long-run equilibrium values. When does that overshooting constitute a speculative bubble? That is, how much higher than fundamental economic value must house prices go to constitute a *speculative* bubble?

In any event, identifying speculative bubbles requires some estimate of fundamental economic value. This has led analysts to incorporate two categories of variables that determine house prices. One set that models long-run equilibrium house prices; a second set that describes short-run movements towards the long-run equilibrium. Fundamental economic values for housing have been estimated using: (1) a weighted average of past long-run equilibrium house prices; (2) historical house price to household income ratios; (3) historical house price to rent ratios; and (4) comparisons of user costs of owner-occupied housing to rents.

Abraham and Hendershott (AH, 1993, 1996) start with the basic Capozza and Helsley (1989, 1990) housing market model. Variables that determine long-run equilibrium relate to the standard determinants of housing supply and demand. Variables that explain short-run dynamic behavior in house prices include lagged house prices and the difference between actual and long-run equilibrium house prices. AH (1993) employ a reduced form model that relates changes in long-run equilibrium house prices to changes in construction costs, real per working age adult income, employment, and real after tax interest rates. They report that real income growth and changes in after tax real interest rates explain about half of the historical variation in house price appreciation rates. AH (1996) divide their sample of 30 metropolitan areas into 16 inland and 14 coastal cities and report that "coastal and inland cities respond similarly to real income growth and the user cost variable (changes in real after-tax interest rates and local price deviation) but quite differently to the disequilibrium variable lagged appreciation rates and deviation of the actual from the equilibrium price level and to construction cost inflation" (p. 198).

Capozza, Hendershott and Mack (2004) examine the housing market adjustment process for 62 metropolitan housing markets from 1979 through 1995. The CHM model relates long-run equilibrium house prices to the size of the metropolitan market (as measured by population and the level of real income), real construction costs, expected population growth, the user-cost of owner-occupied housing and regulatory constraints to real estate development. Short-run house price dynamics are modeled with mean reversion to the long-run equilibrium price, and serial correlation in house prices. Their theoretical house price model reduces to a second order difference equation that depends on three parameters: the serial correlation coefficient; the rate of mean reversion, and a parameter that measures the contemporaneous adjustment to the long-run equilibrium price. The second order difference equation permits different reactions to shocks in the housing market: (1) prices that gradually reach a new equilibrium (without overshooting the new equilibrium); (2) prices that oscillate about, and eventually reach, the new equilibrium; (3) prices that diverge from the new equilibrium exponentially; and (4) prices that diverge from the new equilibrium in an oscillatory pattern. Their empirical results indicate that house prices initially adjust by about 52% of the value of the new long-run equilibrium price and that house prices exhibit serial correlation ($\rho = 0.33$). They also indicate that metropolitan areas with high real construction costs, faster population growth rates and higher rates of growth in real incomes have higher rates of serial correlation. These places tend to overshoot their long-run equilibria. Finally, CHM report that the size of a metropolitan area is positively correlated with the degree of mean reversion in house prices.

Krainer and Wei (2004) calculate the price-rent ratio, or the price-earnings ratio for the U.S. housing market, in Fig. 3. The price series is the existing home sales price index published by OFHEO, a repeat sales index. The rent series is the owner's equivalent rent index published by the Bureau of Labor Statistics (BLS), and measures changes in the price of owner-occupied housing services. Fig. 3 suggests that asset prices are high relative to rents. More precisely, house prices have been growing faster than implied rental values at least from 1997 through 2004. In late 2004, the value of the U.S. price-rent ratio was 18% higher than its long-run average.

In their investigation of housing market bubbles, Malpezzi and Wachter (2005) use a simulation model to illustrate that expectations of house price appreciation play a greater role in determining house prices in markets where housing is inelastically supplied. They conclude "the effects of speculation appear to be dominated by the effect of the price elasticity of supply. In fact, the largest effects of speculation are only observed when supply is inelastic" (p.160).

Thus far the literature provides three broad themes. First, long-run equilibrium house prices are determined by the fundamental economic determinants of housing demand (e.g. household income (or employment and wages), the size of the market, and household preferences) and housing supply (e.g. land prices, prices of operating and construction inputs, geographic and government constraints on development). Second, expectations play an important role in determining short-run house price adjustments to long-run equilibrium. Third, the magnitude of the expectations' influence is related to a metropolitan housing market's supply elasticity.

Empirical estimates of housing supply elasticity vary widely, from the perfectly elastic housing supply elasticities of Muth (1960) and Follain (1979) to the perfectly inelastic supply elasticities of Quigley and Raphael (2005). We expect housing supply elasticities to vary significantly among US metropolitan housing markets. Housing markets in Texas cities are typically not constrained by either geographic or governmental constraints on growth, unlike cities in California. Because the housing supply in Dallas TX is elastic (at least relative to the housing supply in San Francisco CA), equivalent increases in the aggregate demand for owner-occupied housing will result in a much greater price effect for the San Francisco housing market.

Poterba (1984) incorporates credit rationing in his housing market model and, using quarterly data over the 1964:1 to 1982:2 period, estimates the long-run new construction elasticity to be in the +0.5 to +2.3 range. DiPasquale and Wheaton (1994) incorporate a stock adjustment process in their model of housing supply and estimate the long-run price elasticity of new construction to be in the +1.0 to +1.2 range.

Fig. 3. Source: http://www.frbsf.org/publications/economics/letter/2004/el2004-27.html#subhead2.

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Using a housing market model described in Malpezzi and Mayo (1997), Malpezzi and Maclennan (2001) estimate housing supply elasticities for the US and the UK during the pre- and post-war period. They report that stock adjustment models yield elasticities in the +1.0 to +5.0 range for the US and from +0 to +1.0 in the UK. Green et al. (2005) estimate metropolitan area specific new construction elasticities for 45 MSAs over the 1979–1996 period and model spatial variation in those estimated elasticities. They report new construction elasticities ranging from 0 to over 20. They also conclude that metropolitan area supply elasticities are lower in more regulated housing markets and in more densely populated cities.

Goodman (2005b) estimates central city and suburban housing market supply elasticities over the 1970–2000 period using the US Department of Housing and Urban Development's (HUD's) *State of the Cities Data System* (SOCDS). He reports that suburban supply is more elastic than central city supply. He also finds significant spatial variation in the estimated supply elasticities.

We seek to examine a metropolitan housing market's response to an increase in the aggregate demand for owner-occupied housing and how that response varies with the market's ability to produce owner-occupied housing. We contend that housing supply elasticities vary widely among metropolitan housing markets. Estimating housing supply elasticities with national aggregate time series data makes it difficult to identify the underlying spatial variation in supply elasticities. We measure supply elasticities using spatial variation in housing market outcomes from 1990 through 2000.

In addition, owner-occupied housing can be produced from new construction, the stock of rental housing (e.g. condominium conversion), and conversions from non-residential uses (e.g. converting warehouse loft space to condominiums). We are primarily interested in the market's ability to produce completed owner-occupied properties (e.g. land + improvements), not just structures.

We begin with a simulation model. The model posits linear aggregate housing demand and aggregate housing supply equations and asks the question "what increase in the market price of housing is required to support the observed increase in the number of owner-occupied housing units?" The answer clearly depends on elasticities. We then estimate metropolitan housing market specific housing supply elasticities using HUD's *State of the Cities* place data for 133 metropolitan areas across the US.

3. The simulation model

We begin with a simple model of linear aggregate demand and supply curves, and ask:

1. Over the 2000–2005 period what shift in aggregate demand was required to observe a 10.3% increase in the number of owner-occupied housing units in the US over this period?
2. What was the corresponding increase in the equilibrium house price?

We derive the equilibrium levels of output and prices as functions of average price and output, assumed elasticities, and shifts in aggregate demand and supply.

The simulation helps clarify a few issues. First, a 10.3% increase in the equilibrium number of owner-occupied housing units is very different than a 10.3% increase in the aggregate demand for owner-occupied housing. Second, the increase in the equilibrium price required to support the observed 10.3% increase in the number of owner-occupied housing units is very sensitive to the (assumed) supply elasticity, with real appreciation rates ranging from 25% to 127%.

Consider the following model:

$$\text{Aggregate Demand:} \quad Q_{\mathrm{D}} = a + bP, \quad b < 0 \tag{1}$$

$$\text{Demand Elasticity:} \quad E_{\mathrm{D}} = \frac{\mathrm{d}Q_{\mathrm{D}}}{\mathrm{d}P} \cdot \frac{P_{\mathrm{o}}}{Q_{\mathrm{o}}}$$
$$\text{so} \quad b = \frac{\mathrm{d}Q_{\mathrm{D}}}{\mathrm{d}P} = E_{\mathrm{D}} \cdot \frac{Q_{\mathrm{o}}}{P_{\mathrm{o}}} \tag{2}$$

and

$$a = Q_o - E_D Q_o = Q_o[1 - E_D], \text{ leading to}$$

$$Q_D = Q_o[1 - E_D] + [E_D Q_o/P_o]P \quad (1')$$

$$\text{Aggregate Supply:} \quad Q_S = c + eP, \quad e > 0 \quad (3)$$

$$\text{Supply Elasticity:} \quad E_S = \frac{dQ_S}{dP} \cdot \frac{P_o}{Q_o}$$

$$\text{so} \quad e = \frac{dQ_S}{dP} = E_S \cdot \frac{Q_o}{P_o} \quad (4)$$

and

$$c = Q_o - E_S Q_o = Q_o[1 - E_S], \text{ leading to}$$

$$Q_S = Q_o[1 - E_S] + [E_S Q_o/P_o]P \quad (3')$$

The inverse aggregate demand and aggregate supply equations are given by:

$$\text{Inverse Demand:} \quad P = \frac{P_o}{E_D Q_o} Q_D - \frac{P_o}{E_D}[1 - E_D] \quad (5)$$

$$\text{Inverse Supply:} \quad P = \frac{P_o}{E_S Q_o} Q_S - \frac{P_o}{E_S}[1 - E_S] \quad (6)$$

Now suppose there is a parallel increase x in aggregate housing demand:

$$\text{Shift Demand:} \quad P = \frac{P_o}{E_D Q_o} Q'_D - \frac{P_o}{E_D}[1 - E_D] + x \quad (7)$$

This corresponds to a new aggregate demand curve:

$$Q'_D = Q_o[1 - E_D] - [E_D Q_o/P_o]x + [E_D Q_o/P_o]P \quad (8)$$

With no change in supply costs (or production technology), the new equilibrium is:

$$Q'_D = Q_S, \quad \text{or} \quad (9)$$

$$P' = P_o - \frac{E_D}{E_S - E_D} \cdot x \quad (10)$$

The relevant question is how much does aggregate demand have to increase to yield a 10.3% percent increase in the observed number of owner-occupied housing units.

To answer this question, we have evaluated the market at the 2000 average place values for price and output, a *constant* demand elasticity of −0.8 (Goodman, 1988) and a variety of supply elasticities. To get a 10.3% increase in the number of owner-occupied units when the supply elasticity is +2.0 (Table 1 – column 1) requires an 8.0% increase in aggregate demand (column 2) and a 5.2% increase in *real house prices* (column 3). With a housing supply elasticity of +0.5, the increase in aggregate demand required to achieve a 10.3% percent increase in the observed number of owner-occupied housing units is 14.9%. The increase in real house prices is 20.6%. The required increase in house prices is very sensitive to housing supply elasticity.

If we include the increase in the real prices of factor inputs that occurred over those five years, the real and nominal price increases are substantially larger. We start with a parallel increase y in the aggregate supply curve:

$$\text{Inverse Supply:} \quad P'' = \frac{P_o}{E_S Q_o} Q''_S - \frac{P_o}{E_S}[1 - E_S] + y \quad (11)$$

This corresponds to a new aggregate supply curve:

$$Q''_S = [E_S Q_o/P_o]P'' + Q_o[1 - E_S] - y[E_S Q_o/P_o]. \quad (12a)$$

With the corresponding aggregate demand equation of:

Table 1
Percent increases in real house prices necessary to achieve a 10.3% increase in the number of owner-occupied housing units for alternative housing supply elasticities ($E_D = -0.8$)

Supply elasticity	Demand shift		Demand + supply shift
	Quantity	Price	
0.10	51.50	103.00	127.00
0.20	28.61	51.50	75.50
0.30	20.98	34.33	58.33
0.40	17.17	25.75	49.75
0.50	14.88	20.60	44.60
0.60	13.35	17.17	41.17
0.70	12.26	14.71	38.71
0.80	11.44	12.88	36.88
0.90	10.81	11.44	35.44
1.00	10.30	10.30	34.30
1.10	9.88	9.36	33.36
1.20	9.54	8.58	32.58
1.30	9.24	7.92	31.92
1.40	8.99	7.36	31.36
1.50	8.77	6.87	30.87
1.60	8.58	6.44	30.44
1.70	8.42	6.06	30.06
1.80	8.27	5.72	29.72
1.90	8.13	5.42	29.42
2.00	8.01	5.15	29.15
3.00	7.25	3.43	27.43
4.00	6.87	2.58	26.58
5.00	6.64	2.06	26.06
6.00	6.49	1.72	25.72
7.00	6.38	1.47	25.47
8.00	6.29	1.29	25.29
9.00	6.23	1.14	25.14
10.00	6.18	1.03	25.03

$$Q''_{\mathrm{D}} = [E_{\mathrm{D}}Q_{\mathrm{o}}/P_{\mathrm{o}}]P'' + Q_{\mathrm{o}}[1 - E_{\mathrm{D}}] - x[E_{\mathrm{D}}Q_{\mathrm{o}}/P_{\mathrm{o}}], \tag{12b}$$

the new equilibrium is:

$$Q''_{\mathrm{D}} = Q''_{\mathrm{S}} \tag{13}$$

and

$$P'' = P_0 + \frac{yE_{\mathrm{S}} - xE_{\mathrm{D}}}{E_{\mathrm{S}} - E_{\mathrm{D}}} \tag{14}$$

Column 4 of Table 1 provides the corresponding increases in real house prices required to increase the observed housing stock to the new equilibrium (evaluated at $E_{\mathrm{D}} = -0.8$ and a variety of supply elasticities) with 24% higher supply costs. If the supply elasticity is +2.0, real house prices must increase by 29.2% (instead of 5.2%). With a housing supply elasticity of +0.5, real house prices must increase by 44.6% (instead of 20.6%).

4. The empirical model

Our objective in this section is to determine how much of the increase in real house prices observed over the 2000–2005 period can be attributed to changes in the underlying economic determinants of house prices. We begin with a long-run equilibrium housing market model that explains *across-metropolitan area* variation in house prices. We then modify this model to accommodate the hierarchical nature of within metropolitan area housing submarkets and focus on the market for owner-occupied housing. The model follows Mills and

Hamilton (1994), Malpezzi and Maclennan (2001) and Goodman (2006). In the long run, at time t the aggregate demand for housing (Eq. 15) in a metropolitan area, Q_t^D is a function of household income, Y_t, the price of rental housing services, R_t, and the size of the market as measured by population, H_t. The long-run aggregate quantity of housing supplied, Q_t^S is a function of asset prices, V_t, and supply shifters G_{jt}, $j = 1, \ldots, J$, which we relate to input prices (Eq. 16). In long-run equilibrium Eq. (17), the price of rental housing services equals the user cost ρ_t, which varies positively with mortgage interest, i, asset depreciation, d, and property tax rate, tr, and negatively with expected capital gains, $E\{\dot{p}\}$, multiplied by house value. Finally, Eq. (18) provides the product market equilibrium condition.

$$\text{Demand for Housing Units:} \quad \ln Q_t^D = \alpha \ln Y_t + \beta \ln R_t + \delta \ln H_t + \varepsilon_t^D \tag{15}$$

$$\text{Supply of Housing Units:} \quad \ln Q_t^S = \gamma \ln V_t + \sum_{j=1}^{j=J} \eta_j G_{jt} + \varepsilon_t^S \tag{16}$$

$$\text{Capital Market Equilibrium: User Cost:} \quad R_t = V_t[i + d + tr - E\{\dot{p}\}] \tag{17}$$

$$\text{or} \quad \ln R_t = \ln V_t + \ln \rho_t \tag{17$'$}$$

$$\text{Product Market Equilibrium} \ln Q_t^S = \ln Q_t^D \tag{18}$$

Price elasticity β is expected to be negative with the other behavioral demand and supply elasticities positive. Olsen (1987) notes that "a properly specified relationship explaining long-run supply price will contain either the quantity of the good, or input prices, but not both" (p. 1018). The empirical model relates changes in quantity to changes in price. We include changes in the prices of factor inputs G^j to indicate supply curve shifts over time.

The initial model examines long-term changes in housing values and rents for a metropolitan area. Metropolitan area housing markets are comprised of housing submarkets nested within the larger geography. As such, the 'asset price' for a metropolitan area is a weighted average of house prices for individual submarkets (where the weights are the proportion of the stock, or of transactions, located within the submarket). The aggregate stock of housing for an entire metropolitan area is the sum of the housing stocks within each submarket. Suppose a metropolitan area consists of K_i submarkets and there are q_{ik} housing units located in submarket k (i indexes metropolitan area housing markets). The stock of housing for this metropolitan area is the sum of the stocks for each submarket (with time subscripts omitted):

$$Q_i = \sum_{k=1}^{K_i} q_{ik} \tag{19}$$

If p_{ik} is the submarket's price of housing, the metropolitan area's house price is:

$$P_i = \sum_{k=1}^{K_i} \frac{q_{ik}}{Q_i} p_{ik} \tag{20}$$

4.1. The econometric technique

Solving Eqs. (15)–(18) for Q and V:

$$\ln V_t = \frac{\alpha}{\gamma - \beta} \ln Y_t + \frac{\beta}{\gamma - \beta} \ln \rho_t + \frac{\delta}{\gamma - \beta} \ln H_t - \sum_{j=1}^{j=J} \frac{\eta_j}{\gamma - \beta} G_{jt}, \quad \text{or} \tag{21}$$

$$\ln V_t = \vartheta_1 \ln Y_t + \vartheta_2 \ln \rho_t + \vartheta_3 \ln H_t + \sum_{j=1}^{j=J} \xi_j G_{jt} \tag{21$'$}$$

$$\ln Q_t = \gamma \ln V_t + \sum\nolimits_{j=1}^{j=J} \eta_j G_{jt}. \tag{22}$$

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Eqs. (21′) and (22) are then estimated in difference form to explain the decadal changes. Note that the G_j coefficients in Eq. (21) would be expected to have the opposite signs of those in Eq. (16).

Differencing the values and the rents provides a "repeat" index for units in beginning and at the end of the decade and adjusts for systematic differences in unit size or quality across metropolitan areas. In equation system (23), vectors ϑ and γ are parameters for the value and quantity equations and **z** represents vectors of explanatory variables.

$$\begin{bmatrix} \hat{V} \\ \hat{Q} \end{bmatrix} = \begin{bmatrix} \boldsymbol{\vartheta} & \boldsymbol{\xi} & 0 & 0 \\ 0 & 0 & \gamma & \boldsymbol{\eta} \end{bmatrix} \begin{bmatrix} \hat{\mathbf{z}} \\ \hat{\mathbf{G}} \\ \hat{V}_f \\ \hat{\mathbf{G}} \end{bmatrix} + \begin{bmatrix} u^V \\ u^Q \end{bmatrix} \tag{23}$$

The parameters in (23) will be estimated by *Indirect Least Squares* (ILS). A two-stage ILS estimator will first estimate the value change equation $\hat{V}$ in each decade, and then use the fitted value $\hat{V}_f$ in the quantity change equation $\hat{Q}$. The demand parameters from Eq. (21′) are just identified in this procedure. The supply elasticities from (22) are identified in the $\hat{Q}$ (second stage) equation.

5. The data, econometric technique and empirical results

5.1. The data

Most of the data in this stage of the study come from the US Department of Housing and Urban Development's (HUD's) *State of the Cities Data Systems* (SOCDS). HUD has produced datasets that summarize demographic and economic characteristics of the population from the 1970 through the 2000 Census.[4]

We begin our analyses with the 9180 places with positive populations in 1990 and 2000. We supplemented HUD's SOCDS with information on land area (in square kilometers) and location (latitude and longitude) obtained from the 1990 Census; with metropolitan area construction costs from RS Means, with agricultural land prices obtained from the US Department of Agriculture and with BLS data on the CPI.[5]

Table 2 provides a list of variable definitions and descriptive statistics for the data. The average place has about 1000 people per square kilometer, but the range of densities varies from as few as 4 to over 82,000 people per square kilometer. Approximately 6% of the places are also central cities for their respective Metropolitan Statistical Areas (MSAs). The mean distance from any place to the closest central city is 27.9 km and there are 83 places per MSA, with as few as 1 (several) and as many as 287 (Chicago).

In 1990, the average place had just over 17,000 inhabitants and about 7000 housing units. The average vacancy rate in 1990 was about 6.1%, yielding 2.75 persons per household. The mean monthly rent in 1990 was $625 (all dollar values were converted to $2000 using the CPI), the median house value about $133,000 and the median household income $46,600. Over the decade of the 1990s, place population grew about 12% and the number of housing units increased 14%. Real rents were basically constant over the 1990s while real household incomes and real median house values increased about 5% over the ten year period.[6]

From this set of over 9000 places, we will concentrate on those 5911 places in which the number of dwelling units did not decrease and on places located in MSAs containing at least 20 places (we rely on within MSA variation in supply and demand drivers to estimate MSA elasticities). The longevity of housing capital suggests a kinked supply curve in which price decreases will decrease the housing stock much more slowly than price increases will increase it. Goodman (2005a), for example, looking across central cities finds supply elasticities in those central cities with decreasing stocks of between +0.03 and +0.13, with supply elasticities in

[4] HUD's SOCD is available at: http://socds.huduser.org/, last accessed May 6, 2007. In addition to providing information on population and housing characteristics, the site provides information on employment from the Bureau of Labor Statistics' (BLS') County Business Patterns, Crime Statistics from the Federal Bureau of Investigation, public finance data from the Survey of Governments, building permits, and data from the 1990 and 2000 Comprehensive Housing Affordability Strategy surveys.

[5] For the small number of places without cost and agricultural land price data, we sought the closest "similar" market within the same state and assigned the value. Further details are available on request.

[6] Percentage changes were calculated at variable midpoints so % change in $x = \frac{(x_{2000} - x_{1990})}{\frac{(x_{2000} + x_{1990})}{2}} = \frac{2(x_{2000} - x_{1990})}{(x_{2000} + x_{1990})}$. This is appropriate for decadal changes and it has the effect of damping large supply or price increases.

Table 2
Variable definitions and descriptive statistics

Variable	Name	N	Mean	Std Dev	Minimum	Maximum
Place information						
Central City dummy	CC	9180	.06	.24	0.00	1.00
Density/square kilometer	DENSITY	9180	974.	1283	3.56	82,031
Distance to CBD (in kilometers)	DISTANCE	9180	27.92	42.48	0.00	195.00
Number of Places in MSA	NPLACES	9180	83.21	83.78	1.00	287.00
Number of governments per capita	NUMGOV	9180	0.02	0.04	0.00	0.44
1990						
Population	POP90	9180	17,280	103,271	311.0	7,322,564
Total housing units	TOTUN90	9180	658	42,040	251	2,978,686
Occupied housing units	OCCUN90	9180	6476	39,138	142	2,819,401
Persons in owner-occupied units	OWNPERS90	9180	10,648	44,712	0.00	2,424,821
Owner-occupied housing units	OWNOCC90	9180	3762	14,931	0.00	808,901
Occupancy Rate (in %)	OCCRAT90	9180	93.85	4.79	27.63	100.00
Persons per household	HHSIZE90	9175	2.75	0.46	1.34	8.60
Percent minority	PCMINORITY90	9180	13.03	19.65	0.00	100.00
Median rent (2000)	MEDRNT90	9162	625	233	162	1276.00
Median value (2000)	MEDVAL90	9153	132,716	103,964	19,119	637,336
Median income (2000)	MEDINC90	9180	46,597	20,854	9973	201,534
User cost (in %)	RHO90	9135	7.06	2.52	0.98	24.49
2000						
Population	POP00	9180	19,516	112,533	276	8,008,278
Total housing units	TOTUN00	9180	7778	44,519	251	3,172,755
Occupied housing units	OCCUN00	9180	7347	42,064	83	3,021,588
Persons in owner-occupied units	OWNPERS00	9180	12,333	49,597	0.00	2,695,454
Owner-occupied housing units	OWNOCC00	9180	4405	16,655	0.00	912,296
Occupancy rate (in %)	OCCRAT00	9180	94.57	4.12	20.15	100.00
Persons per household	HHSIZE00	9176	2.68	0.46	1.38	9.22
Percent minority	PCMINORITY00	9180	16.79	22.04	0.00	100.00
Median rent (2000)	MEDRNT00	9165	6260	239	96	1936
Median value (2000)	MEDVAL00	9165	138,900	109,909	11,610	967,481
Median income (2000)	MEDINC00	9179	48,809	21,568	9191	200,001
User cost (in %)	RHO00	9151	6.52	2.28	0.53	33.30
Decadal changes (all in %)						
Change in population	POPCH	9180	12.36	24.22	−138.59	185.82
Change in total units	TOTUNCH	9180	13.90	22.78	−139.39	184.63
Change in occupied units	OCCUNCH	9180	14.67	23.33	−137.66	186.79
Change in owner-occupied units	OWNOCCCH	9179	16.35	26.59	−184.16	200.00
Change in occupancy rate	OCCRATCH	9180	0.81	4.80	−115.92	95.80
Change in household size	HHSIZECH	9175	−2.33	6.65	−61.52	96.12
Change in minority households	MINORITYCH	9180	0.42	0.58	−100.00	100.00
Change in median rents	MEDRNTCH	9150	0.59	15.79	−172.07	129.49
Change in median values	MEDVALCH	9146	5.01	23.27	−386.06	77.24
Change in median incomes	MEDINCCH	9179	4.96	12.94	−132.74	104.13
Change in user cost	RHOCH	9117	−7.36	22.17	−170.96	135.22

growing central cities between +1.05 and +1.08. Since we are concentrating on positive bubbles, with growing housing stocks, we limit our empirical analyses to those places with positive growth in number of units.

5.2. The regression results

Table 3 provides the first stage estimates for the housing supply equation. Urban housing theory suggests that supply varies both among and within metropolitan areas. Accordingly we include both MSA mean and individual place values in our estimates. The first stage results indicate that real house price appreciation is positively correlated with household incomes—both in the place and in the broader metropolitan area, neg-

Table 3
First stage regression results for owner-occupied housing

Source	DF	Sum of squares	Mean square	F Value	Pr > F
Analysis of variance					
Model	14	289.69255	20.69232	3907.83	<.0001
Error	5895	31.21459	0.00530		
Corrected total	5909	320.90714			,
Root MSE		0.07277	R-square		0.9027
Dependent mean		0.02558	Adj R-Square		0.9025
Coeff. of variation		284.43614			

Parameter estimates

Variable	Parameter estimate	Standard error	t-Value	Pr>|t|
Intercept	−0.11667	0.00712	−16.4	<.0001
% Change in place median income	0.45117	0.01458	31.0	<.0001
% Change in MSA median income	0.75205	0.02433	30.9	<.0001
% Change in place user cost	−0.56168	0.00950	−59.1	<.0001
% Change in MSA user cost	−0.38815	0.01262	−30.8	<.0001
% Change in place owner population	0.04398	0.00547	8.0	<.0001
% Change in MSA owner population	0.03678	0.00556	6.6	<.0001
Central City	0.04027	0.00323	12.5	<.0001
% Change in agricultural land price	−0.02558	0.00480	−5.3	<.0001
% Change in construction cost	0.21054	0.02640	8.0	<.0001
1990 Density	0.01093	0.00060	18.1	<.0001
Log (distance to nearest CBD)	0.00890	0.00094	9.5	<.0001
Number of MSA governments per capita	−0.28682	0.07240	−4.0	<.0001
% Change in minority households	−0.01499	0.00310	−4.8	<.0001
% Change in household size	−0.04424	0.02099	−2.1	0.0350

The dependent variable is the percentage change in value.

atively related to user costs, and positively correlated with population growth (both in the place and in the broader metropolitan area). Recall from Eq. (21) that supply shifters enter the reduced form value equation with *opposite* signs, so the signs on real construction costs and agricultural land prices (expected to be positive) should be interpreted appropriately. Location matters in that house prices in central cities increase faster than suburban house prices. House prices also increase faster in more densely populated places. Finally, house price appreciation is lower in places where many local governments compete for residents.

We first estimated the second stage coefficients using OLS. An analysis of the residuals indicated that the residual variance was related to the MSA, with higher residual variance in MSAs reporting higher rates of house price appreciation. We subsequently re-estimated coefficients using a one-iteration weighted least squares estimator where the weight was (inversely) proportional to the MSA residual standard deviation.

Table 4 provides second stage results. Local markets' capabilities to produce owner-occupied housing are significantly lower for places with higher rates of increase in agricultural land prices and in real construction costs. The housing stocks in central cities and in densely populated places are less responsive to increases in housing demand and a local housing market's ability to produce owner-occupied housing increases with distance to the closest central city. The estimated coefficients for metropolitan areas' responsiveness to changes in price vary widely. As noted in Table 5, 71.4% (or 95) of the 133 elasticities are positive, and 84 of them, or 63.2% of the 133 are significantly positive at the 10 percent level (1-tailed test, because meaningful supply elasticities cannot be negative). The mean elasticity within metropolitan areas is +0.35, with a median of +0.30. Limiting the analyses to those areas with positive elasticities yields a mean of +0.62 (median of +0.60).

Grouping the elasticities by state and by region provides some additional insights. Mean or median elasticities for Michigan and Ohio are approximately zero, and the supply elasticities for cities in the North Central region are systematically smaller than in other regions. Elasticities in Florida (median for 12 MSAs of +0.18) are systematically smaller than elsewhere in the South as well as the rest of the country.

Table 4
Two stage weighted ILS estimates owner occupied housing

Source	DF	Sum of squares	Mean square	*F* Value	Pr>*F*
Analysis of variance					
Model	141	4034.41925	28.61290	256.33	<.0001
Error	5768	643.86039	0.11163		
Corrected total	5909	4678.27964			
Root MSE		0.33411	*R*-Square		0.8624
Dependent Mean		0.12235	Adj *R*-Square		0.8590
Coeff. var		273.08275			

Parameter estimates

Variable	Parameter estimate	Standard error	*t* value	Prob>|t|
Intercept	0.544	0.0099	54.8	<.0001
% Change in agricultural land price	−0.161	0.0058	−27.7	<.0001
% Change in construction cost	−1.090	0.0400	−27.2	<.0001
Central City	−0.041	0.0030	−13.5	<.0001
1990 Density	−0.024	0.0009	−27.2	<.0001
Log (Distance to nearest CBD)	0.016	0.0009	17.2	<.0001
Number of governments per 1000	0.030	0.0600	0.5	0.6185
Akron	−0.359	0.0522	−6.9	<.0001
Albany NY	0.651	0.0346	18.8	<.0001
Albuquerque	−0.258	0.0586	−4.4	<.0001
Allentown	0.942	0.0471	20.0	<.0001
Ann Arbor	0.458	0.0786	5.8	<.0001
Appleton	0.259	0.0485	5.4	<.0001
Atlanta	0.173	0.0489	3.5	0.0004
Atlantic City	1.006	0.1379	7.3	<.0001
Austin	1.036	0.0446	23.3	<.0001
Bakersfield	−0.089	0.1557	−0.6	0.5668
Baltimore	0.701	0.0373	18.8	<.0001
Bangor	1.287	0.1579	8.2	<.0001
Baton Rouge	−0.233	0.0530	−4.4	<.0001
Bergen-Passaic	0.143	0.0238	6.0	<.0001
Biloxi	1.059	0.1548	6.8	<.0001
Birmingham	0.662	0.0793	8.4	<.0001
Boston	0.000	0.0339	0.0	0.9957
Brazoria	0.819	0.1929	4.3	<.0001
Buffalo	1.485	0.0891	16.7	<.0001
Burlington	−0.046	0.1123	−0.4	0.684
Charleston SC	1.370	0.0631	21.7	<.0001
Charleston WV	−0.459	0.3021	−1.5	0.1285
Charlotte	0.760	0.0414	18.4	<.0001
Chattanooga	−0.631	0.0553	−11.4	<.0001
Chicago	0.258	0.0216	12.0	<.0001
Cincinnati	0.026	0.0756	0.4	0.7269
Cleveland	−0.364	0.0194	−18.8	<.0001
Columbus OH	0.596	0.0371	16.1	<.0001
Dallas	0.942	0.0530	17.8	<.0001
Davenport	−0.001	0.0334	0.0	0.9872
Dayton	0.383	0.2396	1.6	0.1098
Daytona Beach	0.271	0.2432	1.1	0.2654
Denver	0.305	0.0162	18.9	<.0001
Des Moines	0.036	0.0870	0.4	0.6774
Detroit	0.024	0.0177	1.4	0.174
Duluth	−0.094	0.0572	−1.6	0.1024
Poughkeepsie	0.591	0.0619	9.6	<.0001
Fayetteville AR	0.625	0.0468	13.3	<.0001
Fort Lauderdale	−0.015	0.0894	−0.2	0.8661
Fort Myers	1.598	0.1911	8.4	<.0001

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Table 4 (*continued*)

Variable	Parameter estimate	Standard error	t value	Prob>|t|
Fort Pierce	−0.395	0.3132	−1.3	0.2078
Fort Wayne	0.404	0.0746	5.4	<.0001
Fort Worth	0.447	0.0415	10.8	<.0001
Fresno	0.247	0.0794	3.1	0.0019
Gary	−0.091	0.0707	−1.3	0.1995
Grand Rapids	−0.204	0.0240	−8.5	<.0001
Greensboro	0.557	0.0741	7.5	<.0001
Greenville	−0.731	0.1955	−3.7	0.0002
Harrisburg	−1.370	0.2819	−4.9	<.0001
Hartford	0.257	0.0205	12.5	<.0001
Hickory	0.107	0.1551	0.7	0.4915
Honolulu CDP	0.748	0.0646	11.6	<.0001
Houston	1.012	0.1385	7.3	<.0001
Huntington	−0.451	0.7424	−0.6	0.5435
Indianapolis	0.283	0.0415	6.8	<.0001
Jacksonville FL	0.324	0.0567	5.7	<.0001
Johnson City	0.185	0.1568	1.2	0.2385
Johnstown	−0.238	0.1800	−1.3	0.1855
Kalamazoo	−0.217	0.0258	−8.4	<.0001
Kansas City	0.555	0.0572	9.7	<.0001
Knoxville	−0.101	0.0774	−1.3	0.1938
Lafayette LA	0.063	0.1121	0.6	0.5761
Lakeland	−0.282	0.4115	−0.7	0.4929
Lancaster	0.365	0.2074	1.8	0.0784
Lansing	0.029	0.1295	0.2	0.8249
Las Vegas	2.978	0.0952	31.3	<.0001
Little Rock	−0.074	0.2016	−0.4	0.7151
Los Angeles	0.560	0.0134	41.9	<.0001
Louisville	0.055	0.0306	1.8	0.0731
Madison	0.550	0.0416	13.2	<.0001
McAllen	1.223	0.1261	9.7	<.0001
Melbourne	−0.125	0.1292	−1.0	0.3346
Memphis	1.520	0.0947	16.1	<.0001
Miami	0.278	0.0744	3.7	0.0002
Middlesex NJ	0.641	0.0236	27.2	<.0001
Milwaukee	0.644	0.0533	12.1	<.0001
Minneapolis	0.862	0.0334	25.8	<.0001
Mobile	−0.188	0.2310	−0.8	0.4155
Monmouth NJ	0.598	0.1118	5.4	<.0001
Nashville-Davidson	1.038	0.0755	13.8	<.0001
Nassau-Suffolk	0.740	0.0586	12.6	<.0001
New Haven	0.479	0.0299	16.0	<.0001
New London	−0.276	0.0930	−3.0	0.003
New Orleans	−0.339	0.0851	−4.0	<.0001
New York	−1.086	0.0429	−25.3	<.0001
Newark	0.268	0.0315	8.5	<.0001
Newburgh	0.627	0.0136	46.1	<.0001
Oakland	0.686	0.0884	7.8	<.0001
Oklahoma City	−0.577	0.0956	−6.0	<.0001
Omaha	0.128	0.0330	3.9	0.0001
Orange County CA	0.846	0.0230	36.8	<.0001
Orlando	1.067	0.0856	12.5	<.0001
Peoria	−0.310	0.0226	−13.7	<.0001
Philadelphia	0.361	0.0319	11.3	<.0001
Phoenix	1.016	0.0547	18.6	<.0001
Pittsburgh	−0.562	0.1192	−4.7	<.0001
Pittsfield	0.832	0.0850	9.8	<.0001
Portland ME	0.651	0.1403	4.6	<.0001

(*continued on next page*)

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Table 4 (*continued*)

Variable	Parameter estimate	Standard error	*t* value	Prob>|t|
Portland OR	0.334	0.0221	15.1	<.0001
Providence	0.116	0.0187	6.2	<.0001
Raleigh	1.235	0.0679	18.2	<.0001
Reading	0.819	0.1731	4.7	<.0001
Richmond	1.155	0.2403	4.8	<.0001
Riverside	0.763	0.0350	21.8	<.0001
Rochester NY	0.715	0.0480	14.9	<.0001
Rockford	0.269	0.0815	3.3	0.001
Sacramento	1.146	0.1016	11.3	<.0001
Saginaw	0.056	0.0862	0.7	0.5146
St. Louis	0.947	0.0866	10.9	<.0001
Salt Lake City	0.300	0.0357	8.4	<.0001
San Antonio	1.284	0.0764	16.8	<.0001
San Diego	1.718	0.0947	18.2	<.0001
San Francisco	0.360	0.0704	5.1	<.0001
San Jose	−0.704	0.0373	−18.9	<.0001
Santa Rosa	0.787	0.2740	2.9	0.0041
Sarasota	0.039	0.2228	0.2	0.8618
Scranton	−1.016	0.4571	−2.2	0.0263
Seattle	0.364	0.0369	9.9	<.0001
Springfield IL	0.042	0.0549	0.8	0.4426
Springfield MA	0.240	0.0576	4.2	<.0001
Syracuse	0.748	0.0799	9.4	<.0001
Tacoma	0.086	0.0497	1.7	0.0832
Tampa	0.761	0.1174	6.5	<.0001
Toledo	−0.383	0.1113	−3.4	0.0006
Tulsa	−0.333	0.2848	−1.2	0.2421
Utica	1.175	0.2343	5.0	<.0001
Visalia	−0.339	0.1421	−2.4	0.0169
Washington DC	0.438	0.0395	11.1	<.0001
West Palm Beach	0.090	0.1688	0.5	0.5946
Wichita	−0.288	0.0470	−6.1	<.0001
Wilmington NC	0.642	0.0605	10.6	<.0001
York	0.632	0.4686	1.4	0.1774
Youngstown	−0.747	0.0689	−10.8	<.0001

Table 5
Elasticities within and among metropolitan areas

	Mean	Median	Pct correct sign	Pct significant 10% Sig.
Within metropolitan areas				
Supply price (all)	0.3457	0.3050	71.4	63.2
Supply price (+ only)	0.6181	0.5960		
Supply price (neg. set to 0)	0.4508	0.3050		
Demand price	−0.4430	−0.4030		
Demand income	0.3559	0.3237		
Among metropolitan areas				
Supply price	0.3457			
Demand price	−0.2193			
Demand income	0.4250			

Although California reputedly has very strict land-use controls and other constraints on building, the median supply elasticity for the 12 California MSAs exceeds +0.6. Texas shows a median elasticity of 1.01, with the largest elasticity of +1.28 in San Antonio, and the smallest (+0.45) in Fort Worth.

Table 5 also shows the demand price and income elasticities that can be derived from Eq. (21). Within metropolitan areas, the mean price elasticity is −0.44. The mean income elasticity is +0.36.

We interpret the impacts of mean user cost ρ and mean per capita income to relate to variation *among* (as opposed to within) metropolitan areas. We do not estimate aggregate supply coefficients, but using the mean metropolitan elasticity of +0.35, we calculate the price and income demand elasticities among metropolitan areas as −0.22, and +0.42, respectively.

6. Where are the house price bubbles?

In this section we compare observed appreciation rates from 2000 through 2005 to the rates that are driven by the economic fundamentals that we have estimated for the "non-bubble" 1990s. To do this, we use adjusted supply elasticities by evaluating the second stage coefficients at the average place distance and place densities. In no case (results available on request) does this adjustment influence the Table 4 estimate of the supply elasticities by more than 0.05, and in no case does the sign of the elasticity change.

We use the adjusted supply elasticities to compute *expected rates* of appreciation given MSA-specific percentage increases in the observed number of owner occupied units, a 24% real increase in supply costs and a demand price elasticity of −0.8 for MSAs with statistically significant positive supply elasticities. We convert the real rates to nominal using the Consumer Price Index and we compare the expected nominal appreciation rates to the rates that were observed over the 2000–2005 period (the observed appreciation rates are from OFHEO).

The MSA-specific owner-occupied unit percentage changes from 2000 through 2005 were calculated from the American Community Survey (ACS), 2005 (see U.S. Census Bureau *Design and Methodology*, 2006). This database, only recently available, uses a series of monthly samples to produce annually updated data for the same small areas (census tracts and block groups) as the decennial census long-form sample formerly surveyed. The ACS reports estimates for characteristics of the population, households and housing for the nation, for metropolitan statistical areas, and for the largest counties in the US.

Table 6 shows 2000–2005 percentage changes in owner-occupied units calculated at the MSA level by building up county-level data for the 84 MSAs with positive supply price elasticities. The estimates of percentage changes in the number of owner-occupied households over the 2000–2005 period range from −0.62% in Greensboro (the only negative value) to +31.8% for Phoenix. The mean percentage change was slightly over 10.0% and the median was almost 8.4%. Several California MSAs in particular had growth rates less than the mean, including San Diego, Oakland, San Francisco, Los Angeles, Orange County, and Santa Rosa. (source: US Census Bureau, Current Housing Reports, 2000, 2006).

Our calculations are reported in two parts. Table 7A lists those MSAs that experienced greater than expected rates of appreciation in house prices while 7B lists the MSAs that experienced less appreciation than expected.

Of the 84 metropolitan areas examined, 45 experienced *less* appreciation than expected given the significant increase in aggregate housing demand and the increase in real supply prices, while 39 experienced more appreciation. Representing a possible bubble (Table 7A), nominal house prices in Orange County increased 149.7% over the 2000–2005 period. The expected nominal appreciation rate for this period was 51.1%. Consequently, Orange County house prices increased 98.5% more than can be justified from the economic fundamentals. Of the twenty largest differentials (ranging from 98.5% down to 46.6%), eight (of the top eleven) were in California, two (Miami and Tampa) were in Florida, and six (Monmouth NJ, Nassau-Suffolk, Atlantic City, Middlesex NJ, Poughkeepsie, and Newburgh) were within 100 miles of New York City.

In contrast, prices in Atlanta (Table 7B) increased 36% nominally over the 2000–2005 period. The expected nominal appreciation was 151.5%. It would seem therefore, that Atlanta house prices lagged the bubble by a substantial amount. Every city in our sample from Texas (San Antonio, Brazoria, Houston, Austin, Dallas, McAllen, and Fort Worth) lagged the bubble as well.

Among the MSAs in Tables 7A and 7B, the mean annual expected appreciation was +10.7%; the mean observed appreciation was 10.9%. On average, the observed five-year appreciation rates (72.6%) are 1.8 percentage points higher than expected appreciation rates (70.8%).

Our forecast errors come out close to zero, and it is legitimate to ask whether the techniques used would produce a distribution of forecast errors with a mean of near zero under all circumstances. In other words, are we simply getting random results from a well-specified model?

Table 6
Percent change in owner-occupied units (2000–2005) by MSA in descending order

MSA Name	Percent change in owner-occupied units (2000–2005)	MSA Name	Percent change in owner-occupied units (2000–2005)
Phoenix	31.78	Tacoma	8.20
Las Vegas	25.24	Hartford	8.16
Fort Myers	22.33	Poughkeepsie	7.81
Orlando	22.33	Detroit	7.39
Jacksonville FL	19.58	Baltimore	7.33
Atlanta	19.57	Miami	7.14
McAllen	19.28	St. Louis	6.72
Minneapolis	19.25	Biloxi	6.63
Washington DC	18.96	Bergen-Passaic	6.61
Riverside	18.56	Middlesex NJ	6.61
Austin	16.80	Monmouth NJ	6.61
Raleigh	16.63	Nassau-Suffolk	6.61
Appleton	16.27	Newark	6.61
Indianapolis	16.06	Newburgh	6.61
Sacramento	15.89	Salt Lake City	6.61
Charlotte	15.78	Portland ME	6.20
Brazoria	15.40	Reading	6.09
Columbus OH	15.29	Albany NY	5.68
Nashville-Davidson	15.28	Louisville	5.59
Chicago	14.35	New Haven	5.48
San Antonio	14.01	Bangor	5.31
Wilmington NC	13.81	Dayton	5.22
Memphis	13.57	Fort Wayne	5.12
Fayetteville AR	13.55	Rochester NY	5.04
Dallas	12.88	Birmingham	5.00
Fort Worth	12.88	Oakland	4.95
Madison	12.87	San Francisco	4.95
Houston	12.17	Lancaster	4.92
Tampa	12.01	Philadelphia	4.55
Denver	11.73	Rockford	4.50
Ann Arbor	10.98	Syracuse	4.47
Honolulu CDP	10.81	Los Angeles	4.42
Kansas City	10.72	Orange County CA	4.42
Fresno	10.50	Providence	3.86
Milwaukee	10.13	Santa Rosa	2.72
San Diego	9.86	Utica	2.04
Omaha	9.81	Buffalo	1.94
Allentown	9.61	Springfield MA	1.04
Charleston SC	9.56	Pittsfield	0.43
Portland OR	9.49	Greensboro	−0.62
Atlantic City	9.38		
Richmond	8.52		
York	8.36	Mean	10.11
Seattle	8.20	Median	8.44

We respond that our predictions are "out-of-sample." We are not using the same independent variables that were used to perform the original analysis. Under these conditions there are no particular reasons to expect equal numbers of positives and negatives, or predictions that sum to zero, either exactly or approximately. Moreover, there is a geographic regularity to the results, with the high observed nominal appreciation occurring near the coasts, and in the South, and with low observed nominal appreciation occurring in the interior of the country. While we are not explicitly measuring buyer expectations, this geographic distribution seems to mirror the widely recognized perception of unrealistic buyer expectations in particular housing markets.

Table 7A
Where's the bubble? House prices *higher* than expected

Metropolitan Area	Expected nominal appreciation (in %)	Observed nominal appreciation (in %)	Observed less expected (in %)
Orange (California)	51.15	149.66	98.51
Los Angeles	54.74	151.32	96.58
San Diego	51.64	147.72	96.08
Sacramento	60.79	154.17	93.38
Fort Myers	61.16	151.69	90.53
Riverside	72.53	160.76	88.23
Oakland	53.30	133.27	79.98
Monmouth NJ	56.98	135.94	78.96
Santa Rosa	48.96	127.68	78.72
Miami	75.96	146.01	70.05
Fresno	89.84	155.68	65.84
Nassau-Suffolk	54.80	118.90	64.11
Atlantic City	55.53	118.04	62.51
Las Vegas	54.75	115.31	60.55
Middlesex NJ	56.76	114.71	57.95
Poughkeepsie	59.86	111.73	51.88
Baltimore	56.86	107.49	50.63
Tampa	62.98	113.37	50.39
Newburgh	56.95	106.38	49.43
Honolulu CDP	61.80	108.37	46.57
Washington DC	94.11	136.49	42.38
Orlando	68.83	110.29	41.46
San Francisco	60.52	96.68	36.16
Portland ME	56.48	88.23	31.75
Springfield MA	50.52	80.59	30.07
Pittsfield	45.63	72.93	27.30
New Haven	59.03	85.64	26.61
Philadelphia	59.21	85.65	26.44
Phoenix	80.62	106.41	25.79
Newark	72.98	97.67	24.70
Albany NY	54.90	79.32	24.42
Charleston SC	52.97	68.78	15.81
Bangor	49.86	65.65	15.79
Allentown	56.76	71.37	14.61
Richmond	53.45	66.99	13.54
Wilmington NC	68.47	81.81	13.34
Providence	109.26	117.93	8.67
Reading	53.59	55.82	2.23
Minneapolis	69.95	72.05	2.10

7. Conclusions

This article attempts to identify how much of the recent appreciation in house prices can be attributed to economic fundamentals and how much can be attributed to speculation. After reviewing the relevant literature, we investigate the relationship between house price appreciation rates and supply elasticities using a simulation model of the housing market. The model illustrates that the expected rate of appreciation in house prices is very sensitive to the assumed supply elasticity.

We then produce estimates of metropolitan area supply elasticities using cross-sectional place data obtained from HUD's *State of the Cities* Data System for the ''non-bubble'' 1990–2000 period. Our empirical analysis yielded statistically significant positive supply elasticities for 84 MSAs. Then, using the American Community Survey for 2000–2005 changes, we used computed expected rates of appreciation for these MSAs and compared the expected appreciation rates to the rates observed over the 2000–2005 period. We find that speculation has driven house prices well above levels that can be justified by economic fundamentals in less than half of the cities examined.

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Table 7B
Where's the bubble? House prices *lower* than expected

Metropolitan Area	Expected nominal appreciation (in %)	Observed nominal appreciation (in %)	Observed–expected (in %)
St. Louis	53.07	49.22	−3.85
Utica	46.98	41.93	−5.06
Seattle	69.78	63.46	−6.32
York	60.22	53.38	−6.84
Biloxi	52.13	45.02	−7.11
Syracuse	51.74	43.96	−7.78
Milwaukee	62.72	53.85	−8.87
Buffalo	46.51	35.87	−10.64
Lancaster	60.22	48.84	−11.38
Portland OR	75.98	59.52	−16.46
Birmingham	53.24	36.22	−17.02
Hartford	86.59	68.81	−17.77
Fayetteville AR	69.36	51.10	−18.26
Jacksonville FL	107.44	88.62	−18.82
San Antonio	57.47	37.62	−19.84
Greensboro	43.76	23.12	−20.64
Madison	71.07	49.64	−21.44
Rochester NY	52.80	28.05	−24.76
Houston	58.55	31.12	−27.42
Brazoria	66.96	37.97	−28.99
Kansas City	66.28	37.22	−29.06
Bergen-Passaic	126.75	97.67	−29.07
Nashville-Davidson	61.45	31.76	−29.69
Rockford	62.54	32.42	−30.12
Austin	63.35	33.03	−30.32
Dallas	60.27	27.44	−32.83
Memphis	55.24	21.57	−33.67
Ann Arbor	70.65	34.67	−35.98
Salt Lake City	69.51	33.38	−36.13
Raleigh	60.43	22.37	−38.06
Dayton	60.26	22.10	−38.16
McAllen	63.21	24.89	−38.32
Fort Wayne	58.69	19.83	−38.86
Charlotte	68.46	25.01	−43.45
Columbus OH	73.91	29.73	−44.18
Chicago	105.77	61.42	−44.35
Denver	86.56	41.68	−44.88
Fort Worth	76.44	26.98	−49.46
Tacoma	133.37	73.24	−60.12
Appleton	113.68	34.84	−78.84
Indianapolis	106.12	24.41	−81.71
Omaha	122.12	29.26	−92.86
Louisville	140.02	30.46	−109.56
Atlanta	151.52	35.99	−115.53
Detroit	229.67	29.47	−200.20

Establishing "30% over the expected increase" as a housing bubble threshold, only 25 of the 84 metropolitan areas with significantly positive supply elasticities exceed this threshold. Moreover, with the exception of Las Vegas, every single one of these areas is either within 75 miles of the Atlantic coast or California's Pacific coast, suggesting that extreme speculative activity, so prominently publicized, was extraordinarily localized.

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