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Working Paper 16-02

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Abstract

We document real house price growth accelerations in U.S. ZIP codes between 1975 and 2015. Acceleration episodes, which are defined to include relatively extreme periods of price growth, tend to exhibit temporal clustering and occur with greater frequency in large versus small cities. We exploit within-city variation in price dynamics to provide evidence that growth accelerations initially overshoot sustainable price levels but, in some areas, may reflect positive underlying economic fundamentals. Price levels post-acceleration are most sustainable in large cities, especially near city centers. Dynamics are generally consistent with empirical mean-reversion models and theories regarding the effects of traffic congestion and the elasticity of housing supply on house price gradients within the city.

Keywords: house price cycles · Great Recession · real estate · boom · bust · house price index

JEL Classification: E32 · R30

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1 Introduction

Is a rapid rise in house prices sustainable, or will prices eventually fall? As Case and Shiller (2003) make clear, price dynamics following a permanent, positive demand shock are dependent on the extent of new construction in the area. However, within a city, there is substantial variation in existing density and the supply of buildable sites, causing a demand shock to have different supply responses in different locations. Furthermore, rapid expansion of the supply of housing in a city may exacerbate traffic congestion, increasing the relative desirability of center-city housing. These potentially differential supply and congestion effects of a city-wide demand shock highlight the major issue with city-level analysis—geographic aggregation can easily mask differences in price dynamics within a city. This is emphasized by Mian and Sufi (2009), Guerrieri, Hartley, and Hurst (2013), and others who have examined house price movements since the 1990s, finding broad, differential patterns of house price appreciation rates within cities.

We explore within-city real house price dynamics using a new panel of 5-digit ZIP code house price indices (HPIs) between 1975 and 2015 which spans the entire United States.[1] We then make two contributions, the first of which is to document the incidence of acceleration episodes within and across cities beginning in the early 1980s. Accelerations are defined as cumulative real house price growth in excess of 50% over a four-year period that is at least 22 percentage points higher than the cumulative growth in the prior four-year period.[2] There are four main acceleration periods in the United States since 1980: the private equity boom of the late 1980s, the "dot-com" boom of the late 1990s, the subprime boom of the mid 2000s, and the oil boom of the early 2010s. In general, large cities (over 500,000 housing units in the metropolitan area) experience nearly twice as frequent price accelerations as small cities. Within the city, there is no clear pattern regarding which acceleration episodes occur first within a major cycle, with some time periods led by accelerations in the suburbs (1980s) and others by the center-city (1990s-2010s).[3]

[1]Both Mian and Sufi (2009) and Guerrieri, Hartley, and Hurst (2013) rely on data from the Case-Shiller 5-digit ZIP code house price indices. This data series is proprietary and begins in the late 1980s, with coverage including 1,498 ZIP codes beginning in 1990 (see Column 3 of Table 1 in Guerrieri, Hartley, and Hurst, 2013). The data used in our study is the Bogin, Doerner, and Larson (2016) dataset, which is publicly available and spans nearly six times as many ZIP codes beginning in 1990 (nearly 9,000). This dataset has coverage dating back to the mid 1980s, with over 4,400 beginning before 1980 and over 6,000 before 1985, making it ideal to study within-city house price cycles over a 40 year period.

[2]The cutoffs are a log-difference of 0.4 (approximately 50%) and 0.2 (approximately 22%).

[3]The experience in the 1990s-2000s echoes Guerrieri, Hartley, and Hurst's (2013) finding, but calls into question its generalizability to other house price cycles.

Our second contribution is an analysis of price dynamics following a substantial acceleration. In the first four to five years after an acceleration episode, real house prices fall, irrespective of location or time period. However, the speed and extent of adjustments vary between areas. For instance, prices in large cities fall less than in small cities, and areas near the centers of large cities fall by less than areas in the suburbs. Additionally, cities with an inelastic housing supply, including those with a highly regulated housing market or those in a state of long-run economic decline, experience less of a drop in prices. Finally, cities with falls in real prices prior to the acceleration observe smaller price decreases relative to cities where the acceleration was preceded by a period of slow-but-steady increases.

There is evidence that the initial price declines following an acceleration overshoot on average, as real price changes in years four through eight following an acceleration are generally positive. Overall, when taking into account the full 12 years of analysis (4 years of acceleration and the 8 years post-acceleration), real house prices are, generally, at or above pre-acceleration levels in all city types for all locations within the city. These findings are consistent with a dynamic, rational expectations model with location-specific housing supply constraints, similar to Glaeser, Gyourko, Morales, and Nathanson (2014) or Head, Lloyd-Ellis, and Sun (2014).[4] This theory posits that a permanent demand shift leads to a sharp initial increase in prices. This price response induces new construction, and prices fall over the succeeding years as quantities absorb some of the demand change. Over the course of the next 4 years, prices often fall back to pre-shock levels (or even more in supply-elastic areas) but, subsequently, recover. By 8 years post-acceleration, most areas are above pre-shock levels. It appears as though accelerations are initiated by changes to long-run perceptions of a location's desirability, in the vein of Lee, Seslen, and Wheaton (2015), who posit that a high price level indicates strong current and future expectations of economic fundamentals.

While much of the initial price shock appears to be transitory, certain areas (like the center of large cities) tend to retain a portion of the gains from the acceleration episode, suggesting a permanent increase from a demand change in some periods. For instance, there is broad evidence that lending standards and credit constraints were temporarily relaxed in the subprime boom (Dell'Ariccia, Igan, Laeven, 2012). In this time period, accelerations face greater than 100% four-year mean reversion in many locations, consistent with a model

[4]Following the seminal results of Case and Shiller (1989), Glaeser et al. (2014) find that a \$1 increase in house prices is correlated with a \$0.60 to \$0.80 price increase the following year, but a \$0.16 to \$0.28 price decline over the next five years.

where a construction response combined with a transitory demand change leads to prices falling below prior levels, as shown by Favara and Imbs (2015). If there is no construction response, then real house prices are more likely to be bounded below by the pre-shock levels (Ortalo-Magne and Rady, 2006).

Finally, these results are consistent with increases in commute times observed in U.S. cities over the last 40 years. According to Census data analyzed by McKenzie and Rapino (2011) commute times have risen over a cross-section of U.S. cities. In a city with pre-existing traffic congestion, a city-wide demand shock followed by housing construction will steepen the house price gradient according to the standard urban model (SUM) of Alonso (1964), Mills (1967), and Muth (1969). Our results show greater levels of mean reversion in the suburbs relative to centers of large cities, consistent with this notion, as well as the findings of Bogin, Doerner, and Larson (2016).

In light of these theories, our results suggest an adjustment process where an initial demand shock leads to a period of price acceleration, real house prices overshoot when supply is constrained in the short-run, and then prices eventually adjust to a new equilibrium based upon changes in the housing stock as well as the persistence of the demand shock. Our findings are unique because our local house price data show, across the nation, that differential magnitudes and speeds of adjustment are predictable based on not just city-level characteristics, but sub-market characteristics as well. While these estimates are based on four major episodes and may thus face issues of macroeconomic generalizability, patterns across areas within these episodes appear clear and robust.

The remainder of this paper is structured as follows. Section 2 describes our data sources and acceleration classification method. The location and incidence of real house price accelerations are presented in Section 3. Section 4 explores dynamics following acceleration episodes within cities of different types. Section 5 provides concluding remarks.

2 Measuring Accelerations

We identify growth acceleration episodes by adapting the technique of Hausmann, Pritchett, and Rodrik (2010) as described in their analysis of cross-country GDP growth. Their method requires three criteria to be met in order to classify a period as an acceleration: 1) a growth rate threshold, 2) an acceleration threshold, and 3) a global maximum in the level of the series. The first two restrict the sample to areas with high and increasing growth rates, and the third ensures the acceleration is not a recovery from a prior bust. In this paper, we apply and calibrate these criteria to the study of real house prices in U.S. ZIP codes between 1975 and 2015.

Our base dataset draws from house price indices constructed by Bogin, Doerner, and Larson (2016), who calculate indices for 18,000 ZIP codes using nearly 100 million underlying mortgage transactions. We focus on ZIP codes that include properties that are all within a single Core-Based Statistical Area (CBSA) and that have a populated price index beginning in at least 1990.[5] This limits the analysis to 12,949 ZIP codes. In the United States, house price acceleration episodes are often short (several years), but price level changes are large in magnitude. The cutoff for the first criterion is set at a log-difference of 0.4 (about 50% growth rate) over a four-year period.[6] The second criterion requires the growth rate exceeds the prior four-year growth rate by a log-difference of at least 0.2 (22%).[7] We omit the third criterion, instead preferring to study the dynamics of accelerations preceded by both house price growth and declines.[8]

3 Location and Timing of Accelerations

After applying these criteria, we identify over 4,405 ZIP code-level house price acceleration episodes between 1975 and 2015. Two commonly observed acceleration episode types are illustrated in Figure 1. The first vertical line in each figure indicates the start of the acceleration episode and the second vertical line denotes the end. ZIP code 20003 (in the Capitol Hill neighborhood of the Washington, DC, MSA) depicts an area where an initial downturn is reversed and then sustained; ZIP code 90210 (in the Beverly Hills neighborhood of the Los

[5] CBSA stands for "Core Based Statistical Area." The geographic areas are defined by the White House's Office of Management and Budget using Census data. We rely on the February 2013 definitions. Nominal prices are converted into real terms using the all-goods consumer price index produced by the Bureau of Labor Statistics.

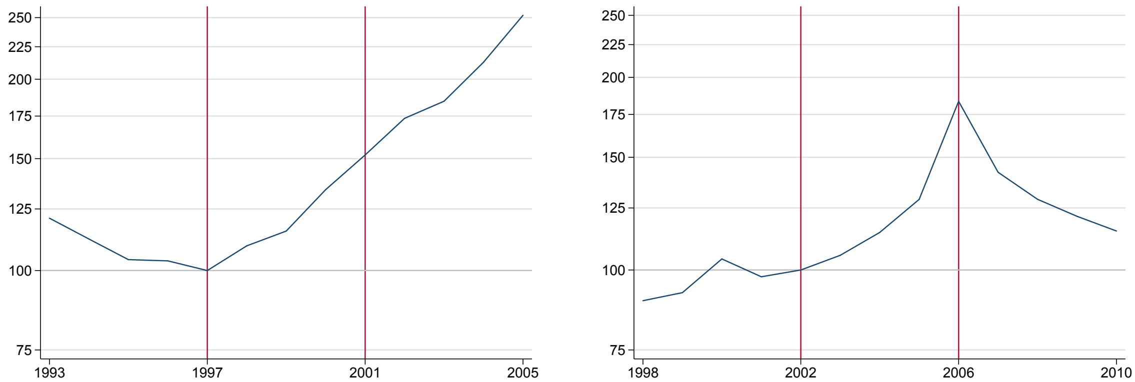
[6] This threshold is chosen because it requires an extraordinary price gain. Robustness tests for this and other criteria are presented in Table 2. The growth rate threshold will affect the number of observed accelerations and the magnitude of results presented later, but the findings are consistent across thresholds.

[7] Growth episodes tend to last between four and eight years. Because four years is the minimum, we set this as the cut-off. In a later section, we conduct robustness tests with different growth cutoffs and time windows. The results are qualitatively similar.

[8] These measures may be vulnerable to estimation error in the indices during the first or fourth year of the acceleration. This may cause inappropriate classifications of acceleration episodes.

Figure 1: Two Examples of Growth Acceleration Episodes

(a) ZIP 20003 (Washington, DC) (b) ZIP 90210 (Los Angeles, CA)



Note: Both figures display a real house price index of cumulative gains with a solid blue line. The first vertical red bar indicates the beginning of an acceleration. The HPI is rebased to start at 100 in that year. The second vertical red bar gives the year the acceleration episode is identified.

Angeles, CA, MSA) illustrates modest growth followed by rapid growth then a correction.[9]

Acceleration episodes occur most frequently in the late 1980s and early 2000s but, as Figure 2 shows, every year has at least one ZIP code with an identified acceleration with the exception of 1993 and 2010.[10] The left panel shows the number of identified accelerations in each year of our sample, which peak in 2005 (with 966 of 12,043 ZIP codes).[11] Because the later years have a greater number of populated indices, we compute another time series for the fraction of ZIP codes with real house price accelerations. Peaks of 7% occur in 1987 and 1989 and a third time at 8% in 2005. We also track ongoing accelerations in the right panel, which are defined as the sum of identified accelerations in the current year and each of the next three years. There are two peaks in this series, in 1986, where 28% of all ZIP codes in the U.S. are accelerating, and 2003, when 21% are accelerating. This second figure highlights the two main peaks and troughs of the major national house price cycles of the last 40 years. This figure also portends the beginning of a third cycle in 2010.

[9] While these two cases are clearly confounded by contemporaneous economic events, necessitating control variables, they serve to illustrate two of the more common dynamic responses to an acceleration episode.

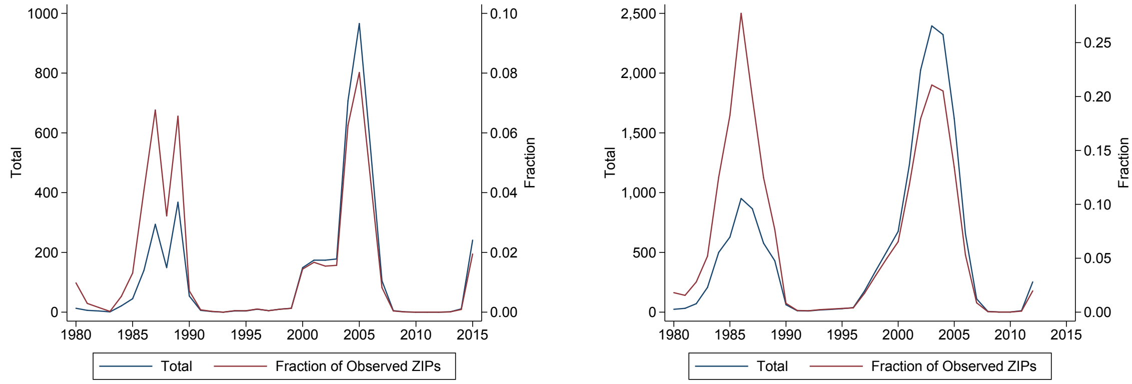
[10] Since it takes four years to identify episodes, we drop ZIP codes before 1980 and where the end of the acceleration is undefined. To preserve data observations, the second criterion is not treated as binding in the first eight years that an index is observed.

[11] To focus on unique acceleration episodes, once a ZIP code has been identified as accelerating it cannot be identified again for another four years.

Figure 2: Real House Price Growth Accelerations in U.S. ZIP codes

(a) Identified Accelerations

(b) Ongoing Accelerations

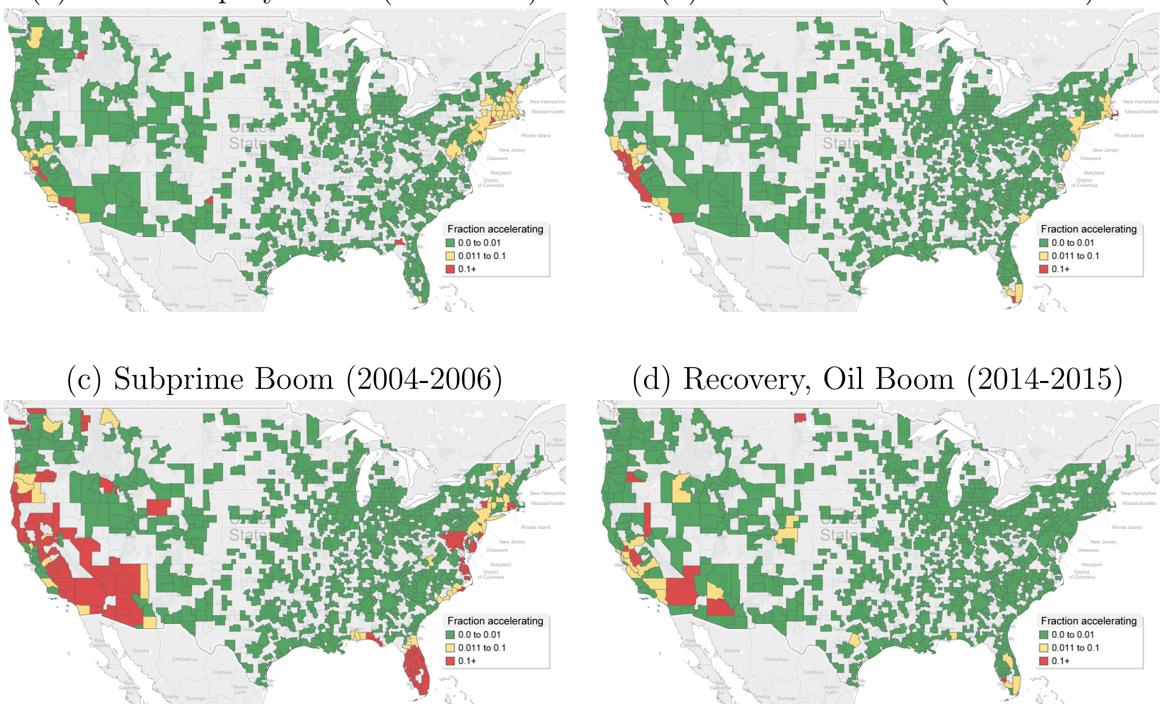


Note: Accelerations episodes are defined as a four-year real house price growth rate of 50% that is 22 percentage points above the prior four-year growth rate. Therefore, accelerations identified in t begin four years prior, $t-4$.

Note: Ongoing accelerations represent ex-post identified accelerations. For a particular year τ, this is calculated as the sum of the identified accelerations (from the left panel) in years τ, $\tau+1$, $\tau+2$, and $\tau+3$. This causes 2013–2015 to be undefined.

Acceleration episodes are clustered in certain ranges of years based on Figure 2. These clusters indicate four major acceleration periods, occurring in 1985-1990, 1999-2003, 2004-2006 and 2014-2015. The first episode coincides with the private equity boom of the late 1980s, and includes rapidly rising house prices in coastal areas and the Pacific northwest. The second episode begins at the end of the "dot-com" boom and continues for several years after the collapse of the tech bubble. This high-acceleration period is limited to the coasts in New England, Florida, and California. For these reasons, we classify it as distinct from the third episode, which is characterized by the massive subprime boom leading up to the Great Recession. This third period shows house price accelerations radiating out from those coastal areas and starting in the southwest. The final period of acceleration coincides with the post-Recession recovery, but some areas that never declined begin accelerating as well, such as those in the oil-rich areas of the Great Plains and Rocky Mountains. The geographic distribution of accelerations in these four periods is shown in Figure 3. A larger fraction of accelerating ZIP codes within a CBSA is depicted with a warmer color shade (e.g., green is 0 to 1%, yellow is 1% to 10%, and red is above 10%). Across the maps, the warmest colors consistently appear in regions like California, Florida and the northeast.

Figure 3: Major Periods of House Price Acceleration



(a) Private Equity Boom (1985-1990) (b) Dot-Com Boom (1999-2003)

(c) Subprime Boom (2004-2006) (d) Recovery, Oil Boom (2014-2015)

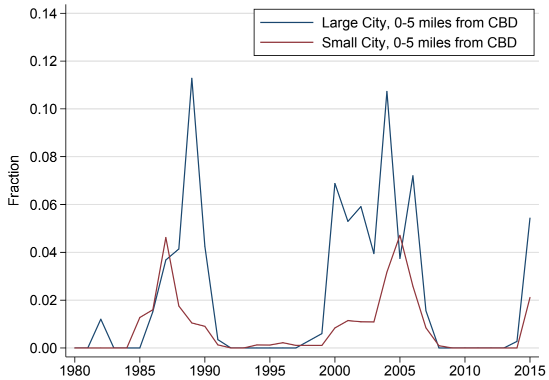
Note: The "fraction accelerating" is the share of ZIP codes that are accelerating in a CBSA over the entire time period.

A major advantage of geographically disaggregated data is that we can go from a national to a local scope to investigate accelerations at different locations within a city. We label four main sub-regions within the city: the center-city, mid-city, suburbs, and exurbs. The center-city represents ZIP codes less than 5 miles from the Central Business District (CBD); the mid-city falls between 5 and 15 miles; the suburbs are between 15 and 25 miles; and the exurbs are ZIP codes greater than 25 miles from the CBD.[12] We also distinguish between ZIP codes in large cities (with greater than 500,000 housing units) and small cities.

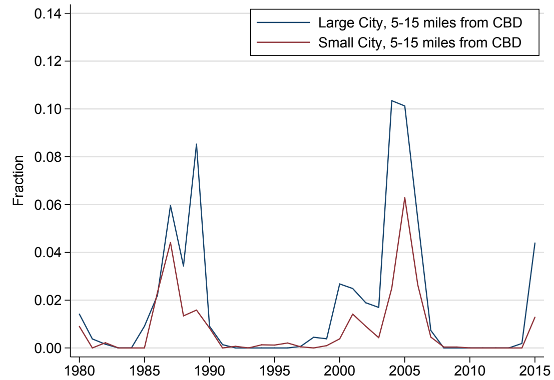
[12]The CBD ZIP code is calculated as the maximum value within the CBSA of the inverse of the standardized land area plus the standardized share of housing units in 20+ unit structures. Land area data are from the Census' TIGER line shapefiles, and structure type is from the 1990 Decennial Census, the earliest census for which ZIP code data are available. Distance to the CBD is calculated as the distance between a ZIP code's centroid and the CBD ZIP code's centroid.

Figure 4: Accelerations by City Size and Location in City

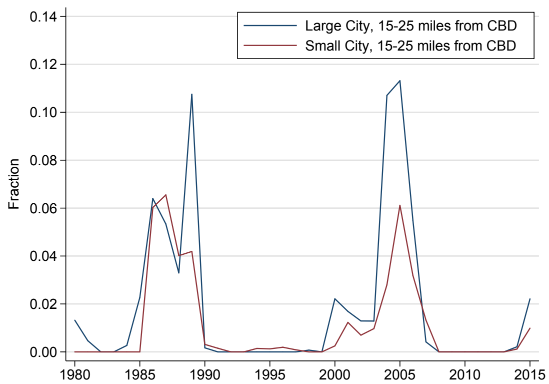
(a) 0-5 Miles from CBD



(b) 5-15 Miles from CBD



(c) 15-25 Miles from CBD



(d) 25+ Miles from CBD

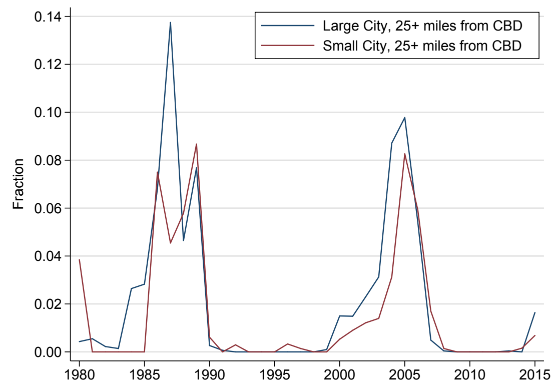


Figure 4 shows the frequency of accelerations, separated by distance from the CBD and the overall size of the CBSA. Several patterns emerge from this breakdown. First, growth accelerations occur at greater rates in large cities versus small cities at nearly all points in time. Second, there is no clear pattern regarding which part of the city "leads" other parts of the city in accelerating within a particular period. In the private equity boom, the suburban accelerations preceded the center-city accelerations. On the other hand, in all other periods, the center-city preceded the suburbs. Third, accelerations tend to occur with similar frequency in different locations within the city.[13] This result echoes the empirical findings of Davidoff (2013), who finds that house price growth occurred in the early 2000s irrespective of housing supply elasticity, and SUM, which hypothesizes that an increase in

[13] An exception to this finding is the period between 1999 and 2003, when accelerations are found primarily in the centers of large cities.

demand for housing in a city raises house prices everywhere in the city due to the within-city iso-utility condition.[14] While different parts of the city may accelerate first, other areas eventually accelerate as well.

4 Are House Price Growth Accelerations Sustainable?

This section explores the degree of mean reversion in real house prices following an acceleration episode. We follow Davis and Weinstein (2002), who use an elegant empirical strategy to measure how the growth of a series might be affected by a shock.[15] Future growth is estimated as a function of the magnitude of a past shock, with the parameter $0 > \beta > -1$ in Equation 1 indicating partial mean reversion, and $\beta = -1$ indicating full mean reversion.[16]

$$\Delta y_{t,t+h} = \alpha + \beta \Delta y_{t-h,t} + \epsilon \tag{1}$$

This equation includes time period fixed effects to control for national trends, and time period clustering of residuals to account for period-specific variance. It is estimated over a sample consisting of identified growth accelerations. Several sub-samples are considered, including pre-2000, post-2000, and if the acceleration was preceded by a four-year decline in prices or a four-year growth in prices. The time period sub-samples serve the purpose of determining the extent of mean reversion with and without the Great Recession. For ease of exposition and comparison, size differences across cities and geography within cities are given mutually exclusive fixed effects with no omitted categories. The parameter estimates for each combination are thus to be interpreted as the full, reduced-form effect.

[14] The SUM assumes that households can freely migrate within a city. This results in a house price gradient within a city as a function of commuting costs, often represented as a function of distance to the CBD. A positive demand shock for housing in a city therefore results in a shift of house prices in all areas of the city. The SUM with one household type and linear transportation costs is incompatible with differential appreciation rates within the city because of Muth's Equation. However, household heterogeneity may give multiple bid rent curves and housing construction in a congested city may cause rotations of the bid-rent curve. Thus, differential dynamics are consistent with simple extensions of the model.

[15] Davis and Weinstein (2002) examine population dynamics in Japan in the years following Allied bombings in World War II.

[16] There is a large body of empirical literature on house prices as mean-reverting series. This is based on the idea that a bubble exists if a price level is in excess of a long-run price/income ratio (Malpezzi, 1999), house price/rental price ratio (Gallin, 2006), or a long-run trend (Smith, et al., 2015). These studies focus on MSAs or states, implicitly assuming that all submarkets within the region behave in the same manner. While these models may be predictive at the city or state level, they are unable to determine conditions related to differential rates of mean reversion within cities.

4.1 Measuring Growth After Accelerations

Mean reversion results after an acceleration episode are presented in Table 1. To describe post-acceleration behavior, the table is split into analyses of two distinct time horizons. Columns 1 to 5 detail real house price growth in the medium-run (four years) while columns 6 to 10 detail house price growth in the long-run (eight years).

Three main findings emerge to describe real house price growth patterns four years after the acceleration episode. First, most areas of cities experience at least 50% mean reversion over the four-year post-acceleration period regardless of the sample period, preceding house price growth conditions, or location within the city. This is striking, because the minimum real house price growth rate to be termed an acceleration is 50%, which suggests that housing in all areas depreciates by at least 25% over the next four years.[17] Second, the level of mean reversion has a consistent ordering. In large cities, the center city has the lowest level of mean reversion and the mid-city has the second lowest level. On the other hand, the suburbs of large cities and all areas of small cities have similar levels of mean reversion. Finally, accelerations preceded by declining real prices are more sustainable in all areas than accelerations preceded by growth.[18]

These results fit well within existing ideas about price dynamics in high versus low housing supply elasticity areas. Because construction is a major mechanism through which prices fall in periods following a positive demand shock in a full information, rational expectations framework, sustained real house price appreciation might be seen as unusual in areas with high supply elasticity. Glaeser, Gyourko, and Saiz (2010) argue that such areas are unlikely to experience prolonged real appreciation and prices are likely to fall back towards housing input costs as supply responds. Any real appreciation, therefore, may be ephemeral.

Similarly, these results reflect the predicted rotation of the bid-rent curve in a city with congestion with an increase in housing supply. In the standard urban model (SUM) of Alonso (1964), Mills (1967), and Muth (1969), an increase in transportation costs per mile increases

[17] Note that a real decline in house prices of 25% over four years will be due, in part, to inflation. Therefore, in periods with positive inflation, nominal price declines are lower. For instance, with an annual average rate of inflation of 2% per year, a real decline of 25% gives a nominal decline of approximately 17%.

[18] Two potential sources of bias should be noted that are both related to estimation error in the house price indices. The first biases results towards the finding of mean reversion, and is due to left-censoring of episodes classified as accelerations. The second biases results towards the finding of permanent effects, and is caused by attenuation in β.

Table 1: Real House Price Growth Following Acceleration

	LHS Variable: Medium-Run HPI Growth (t, t+4)					LHS Variable: Long-Run Price Growth (t, t+8)				
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Sample	All	Post 2000	Pre 2000	Prior Price Decline	Prior Price Growth	All	Post 2000	Pre 2000	Prior Price Decline	Prior Price Growth
Growth(t-4, t) × :										
Center-City × Large City	-0.932***	-1.191***	-0.395***	-0.769***	-0.966***	-0.516***	-0.529**	-0.394***	-0.528***	-0.532***
	[0.203]	[0.261]	[0.0942]	[0.133]	[0.230]	[0.0969]	[0.196]	[0.0805]	[0.157]	[0.102]
Mid-City × Large City	-1.005***	-1.273***	-0.466***	-0.833***	-1.048***	-0.659***	-0.693**	-0.520***	-0.865***	-0.594***
	[0.227]	[0.306]	[0.0734]	[0.147]	[0.261]	[0.0933]	[0.190]	[0.0934]	[0.127]	[0.103]
Suburbs × Large City	-1.110***	-1.396***	-0.541***	-0.935***	-1.145***	-0.732***	-0.793***	-0.543***	-0.879***	-0.682***
	[0.223]	[0.286]	[0.0909]	[0.153]	[0.257]	[0.107]	[0.203]	[0.0967]	[0.145]	[0.121]
Center-City × Small City	-1.111***	-1.395***	-0.519***	-0.915***	-1.182***	-0.912***	-0.999***	-0.679***	-1.042***	-0.886***
	[0.237]	[0.248]	[0.0978]	[0.148]	[0.283]	[0.0904]	[0.122]	[0.117]	[0.170]	[0.0986]
Mid-City × Small City	-1.199***	-1.501***	-0.531***	-0.942***	-1.284***	-0.960***	-1.054***	-0.675***	-1.003***	-0.957***
	[0.249]	[0.262]	[0.0950]	[0.158]	[0.282]	[0.0980]	[0.156]	[0.108]	[0.162]	[0.110]
Suburbs × Small City	-1.113***	-1.390***	-0.566***	-0.917***	-1.178***	-0.905***	-0.979***	-0.678***	-1.024***	-0.881***
	[0.220]	[0.262]	[0.0941]	[0.137]	[0.247]	[0.0848]	[0.166]	[0.0905]	[0.132]	[0.0958]
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4154	2829	1176	985	3169	4108	2783	1176	980	3128
R-squared	0.756	0.755	0.719	0.861	0.698	0.600	0.466	0.612	0.674	0.533

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The left-hand side variable is the log change in real house prices after the acceleration episode. Center-city is defined as ZIP codes with a centroid between 0 and 5 miles of the CBSA's CBD ZIP code's centroid. Similarly, Mid-City and Suburbs are defined as ZIP codes between 5 and 15 miles, and 15+ miles from the CBD, respectively. Standard errors are adjusted based on clustering by year.

the desirability of center-city housing relative to suburban housing. This congestion effect leads to the prediction that a large house price acceleration, combined with a supply response, will create a permanent, positive price differential between center-cities and suburbs.

In the data, the suburbs of large cities and all areas of small cities exhibit complete mean reversion, with $\beta \leq -1$ in the four years following a growth acceleration episode in all specifications. A point estimate of β less than -1 is consistent with a temporary demand shock combined with a construction response. In an area of this type, a temporary demand increase causes construction. When demand falls to pre-shock levels, the housing stock remains, causing prices to fall below the pre-acceleration level. In the center- and mid-cities of large cities (i.e. areas within 15 miles of the CBD), the extent of mean reversion is less than in other geographic categories, suggesting that the demand shock leading to the acceleration is more permanent and/or the elasticity of housing supply is lower in these types of areas.

In other periods, some real appreciation is maintained in the centers of large cities ($0 > \beta > -1$), even when the acceleration is preceded by a prior price decline in real house prices.[19] Since the SUM requires prices across locations to be linked according to spatial equilibrium conditions, we conclude that some of the appreciation during an acceleration period in a large city is due to a permanent demand increase. In the suburbs, construction increases, causing prices to fall. In small cities, post-acceleration house prices four years later are only sustained if preceded by real price declines, a result that is consistent with equilibrium correction concepts.

Examination of a longer horizon helps to understand the more permanent effects of an acceleration beyond the initial four years. Equation 1 is estimated again with the same four-year acceleration on the right-hand-side, but with the following eight-year growth rate as the dependent variable. Results of this model over the five sub-samples are presented in the second part of Table 1 (columns 6 to 10). Of the three main results in columns 1 to 5 regarding the average level of mean reversion, ordinal rankings between geographic categories

[19]While the hypothesis $\beta = -1$ cannot be rejected for most parameters individually, a parsimonious but less illustrative model can reject the null of no effect of distance from the CBD interacted with city size. This model with clustered standard errors by year in parentheses is:

$$\begin{aligned}\Delta p_{t,t+4} = \alpha_t - 3.70(.32)\Delta p_{t-4,t} - 0.01(.01)k - 0.07(0.01)n + \\ + 0.21(0.02)n\Delta p_{t-4,t} + 0.09(0.03)k\Delta p_{t-4,t} - 0.009(0.002)nk\Delta p_{t-4,t}\end{aligned}$$

where n is the log population and k is the log distance to the CBD.

are maintained in the eight-year period. However, in general, mean reversion is less over eight years than it is over four years. Combined with the four-year post-acceleration results, it appears that real house price cycles follow similar patterns in all areas: an acceleration in prices is followed by real price declines that tend to overshoot initially but, subsequently, recover.

The major implication of these results is that, in the longer run ($t+8$), growth accelerations reflect permanent demand changes. In large cities, prices are consistently higher than the pre-acceleration price level. In small cities, real price gains are weakly positive. Combined with a construction response, however, flat real appreciation is consistent with a permanent, positive demand shift. Growth accelerations might be legitimate signals of a permanent shift in a location's economic fundamentals. This possibility is highlighted by Lee, Seslen, and Wheaton (2015), who develop a model where the house price level is correlated with future appreciation. They argue that a high price level indicates strong current and future expectations of economic fundamentals. In this context, an acceleration in prices could represent a permanent shift of housing demand in an area.

4.2 Robustness Checks and Further Analysis of Dynamics

Our results are potentially sensitive across several dimensions, such as the cutoffs (e.g, for the growth rate, acceleration criterion, and the measurement window) that define house price acceleration episodes. In addition, the empirical methods implicitly assume each acceleration occurs in a representative city of a given size. In reality, elasticity differentials exist across areas, potentially affecting dynamics in predictable ways. Below, we discuss robustness tests related to these assumptions, paying particular attention to post-acceleration dynamics.

4.2.1 Alternative Classification Parameters

Table 2 tests post-acceleration growth rates under different parameter assumptions involved in the creation of the acceleration measures. The first column in Table 2 presents the baseline results in Table 1, column 1. The second and third columns increase and decrease the growth threshold, respectively, and the fourth and fifth columns increase and decrease the acceleration threshold. Finally, the sixth and seventh columns present results of expanding and contracting the window over which the acceleration is measured.

Table 2: Acceleration Parameter Robustness

	LHS Variable: HPI Growth(t, t+4)						
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Adjustment:							
Growth Rate	0.4	0.6	0.2	0.4	0.4	0.4	0.4
Acceleration Criterion	0.2	0.2	0.2	0.3	0.1	0.2	0.2
Window (Years)	4	4	4	4	4	5	3
Growth(t-4, t) × :							
Center-City × Large City	-0.932***	-0.921**	-0.551***	-0.934***	-0.950***	-0.506***	-0.883***
	[0.203]	[0.349]	[0.117]	[0.194]	[0.217]	[0.137]	[0.228]
Mid-City × Large City	-1.005***	-0.976**	-0.679***	-1.054***	-1.016***	-0.560***	-0.939***
	[0.227]	[0.364]	[0.129]	[0.235]	[0.232]	[0.155]	[0.253]
Suburbs × Large City	-1.110***	-1.070***	-0.745***	-1.147***	-1.138***	-0.670***	-1.012***
	[0.223]	[0.351]	[0.133]	[0.232]	[0.234]	[0.157]	[0.248]
Center-City × Small City	-1.111***	-1.109**	-0.751***	-1.167***	-1.136***	-0.660***	-1.061***
	[0.237]	[0.377]	[0.0896]	[0.252]	[0.243]	[0.153]	[0.248]
Mid-City × Small City	-1.199***	-1.119***	-0.828***	-1.245***	-1.227***	-0.733***	-1.067***
	[0.249]	[0.348]	[0.0949]	[0.264]	[0.255]	[0.166]	[0.236]
Suburbs × Small City	-1.113***	-1.046**	-0.770***	-1.150***	-1.146***	-0.663***	-0.982***
	[0.220]	[0.379]	[0.105]	[0.235]	[0.230]	[0.147]	[0.215]
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4154	509	11048	3633	4361	5222	2657
R-squared	0.756	0.574	0.755	0.778	0.749	0.731	0.643

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The left-hand side variable is the log change in real house prices after the acceleration episode. Center-city is defined as ZIP codes with a centroid between 0 and 5 miles of the CBSA's CBD ZIP code's centroid. Similarly, Mid-City and Suburbs are defined as ZIP codes between 5 and 15 miles, and 15+ miles from the CBD, respectively. Standard errors are adjusted based on clustering by year.

Estimates in columns 2 through 7 are broadly consistent with the baseline in column 1. Ordinally, center-cities face less mean-reversion than suburban areas in large cities. In small cities, all types of areas behave similarly. The general level of mean reversion is higher in the baseline than when we impose a five-year window (column 6) or a 0.2 growth rate (column 3) criteria. In contrast, greater mean reversion is observed with three-year window (column 7) or a 0.6 growth rate (column 2) but the observation count decreases significantly.

4.2.2 City-Wide Differences in the Elasticity of Housing Supply

The second set of robustness estimates relaxes the representative city assumption to consider differential dynamics with respect to the elasticity of housing supply. Much of the differences in dynamics in the prior section is attributed to differences in center-city versus suburban elasticities of housing supply in large cities. Following this logic, it is possible that house prices fall slower in low supply elasticity cities compared to high elasticity cities if a demand shock is permanent. There is substantial research on this subject, including Glaeser and Gyourko (2005) who find a lower elasticity of housing supply in areas in long-run economic decline; Glaeser, Gyourko, and Saiz (2008) who present the Wharton Land Use Regulatory Index (WRLURI) and argue that this index acts as a measure of the elasticity of housing supply; and Saiz (2010) who finds restricted topography is associated with supply inelasticity.[20] Overall, theory predicts that high supply elasticity is associated with a greater construction response to a demand shock, implying a higher degree of mean reversion. Therefore, high regulation, high topographic interruption, and cities previously in a state of decline are predicted to have more sustainable levels of real house prices following a growth acceleration when the demand shock leading to the acceleration is permanent.

Table 3 presents results of models investigating whether house price elasticities affect acceleration episodes. The four-year mean reversion is tested across samples partitioned by different housing supply elasticity variables at the sample median for the particular indicator. The first column, again, gives the baseline estimate from the first column of Table 1. Columns 2 and 3 present dynamics in high versus low housing regulation areas, estimated using the WRLURI. While this variable is calculated in the mid-2000s, and may suffer from endogeneity bias, this is the best available variable measuring regulation over a cross-section of cities. Columns 4 and 5 present estimates for samples with high and low levels of topographic interruption, using the elasticity estimates of Saiz (2010). Columns 6 and 7 show differences between cities in long-run decline versus those with stable or growing economies.[21]

[20] The regulation and topography predictions are intuitive at first glance, but the decline prediction may not be. The logic for a lower elasticity of housing supply in a declining area is as follows. Cities in long-run decline often face home values far below the replacement cost of structures. Increases to demand for housing do not often increase the value of the existing housing stock above replacement cost. This demand shock results in limited housing construction, giving a low elasticity of housing supply.

[21] Our long-run urban decline index is the standardized change in the aggregate value of the housing stock between 1970 and 1990. Positive values indicate decline. The housing stock value incorporates both price and quantity changes, making the measure both reflective of demand and invariant to differences in the elasticity of housing supply across areas. This is in contrast to quantity measures such as population and housing stock, which fail to identify demand in inelastic areas.

Table 3: House Price Elasticity Robustness

	LHS Variable: HPI Growth(t, t+4)						
Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sample	All	High Regulation	Low Regulation	High Topographic Interruption	Low Topographic Interruption	Long-Run Economic Decline	Long-Run Economic Growth
Growth × :							
Center-City × Large City	-0.932***	-0.880***	-1.551***	-0.849***	-0.877*	-0.433**	-1.012***
	[0.203]	[0.205]	[0.189]	[0.183]	[0.504]	[0.175]	[0.200]
Mid-City × Large City	-1.005***	-0.961***	-1.571***	-0.903***	-1.125*	-0.223	-1.124***
	[0.227]	[0.233]	[0.135]	[0.199]	[0.575]	[0.149]	[0.229]
Suburbs × Large City	-1.110***	-1.060***	-1.699***	-1.020***	-1.199**	-0.334**	-1.232***
	[0.223]	[0.224]	[0.133]	[0.207]	[0.486]	[0.155]	[0.220]
Center-City × Small City	-1.111***	-1.015***	-1.773***	-1.044***	-1.149***	-0.431**	-1.249***
	[0.237]	[0.208]	[0.254]	[0.265]	[0.388]	[0.201]	[0.227]
Mid-City × Small City	-1.199***	-1.083***	-1.783***	-1.118***	-1.281***	-0.420*	-1.344***
	[0.249]	[0.224]	[0.178]	[0.274]	[0.431]	[0.234]	[0.232]
Suburbs × Small City	-1.113***	-1.054***	-1.664***	-1.043***	-1.132***	-0.432**	-1.240***
	[0.220]	[0.216]	[0.159]	[0.224]	[0.379]	[0.199]	[0.203]
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4154	3887	267	3550	604	836	3318
R-squared	0.756	0.764	0.770	0.772	0.761	0.795	0.765

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The left-hand side variable is the log change in real house prices after the acceleration episode. Center-city is defined as ZIP codes with a centroid between 0 and 5 miles of the CBSA's CBD ZIP code's centroid. Similarly, Mid-City and Suburbs are defined as ZIP codes between 5 and 15 miles, and 15+ miles from the CBD, respectively. Standard errors are adjusted based on clustering by year.

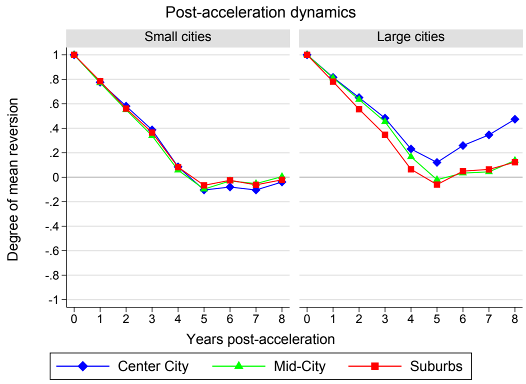
The number of observations in each regression indicate a higher number of growth accelerations in high regulation, high topographically interrupted, and non-declining cities. Because the number of accelerations is not similar across areas of different elasticities, this result reinforces the argument of Davidoff (2014), who argues that supply elasticity measures are often correlated with demand factors. Estimates in this table show that real house price accelerations have less mean reversion in high regulation cities, as is consistent with theory. The degree of topographic interruption appears to have less of an effect on mean reversion. Finally, for areas in long-run decline, in the rare occurrence of a growth acceleration, price dynamics are somewhat more permanent than an equivalent acceleration in a growing area. This result is also consistent with this supply elasticity hypothesis because declining areas have a lower elasticity of housing supply.

4.2.3 Annual Dynamics

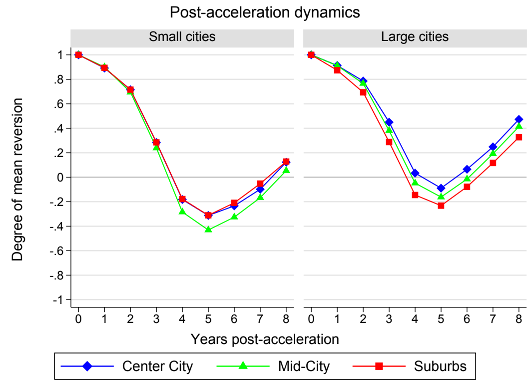
The extent of the mean reversion is defined by the length of the post-acceleration period, or number of years, after the acceleration cycle ends. The length is presented as either 4 or 8

Figure 5: Post-Acceleration Real House Price Growth Dynamics

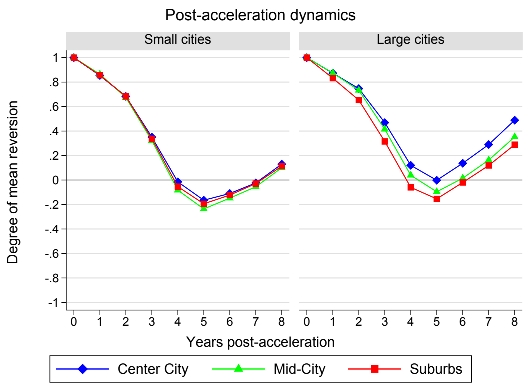
(a) Prior Price Decline



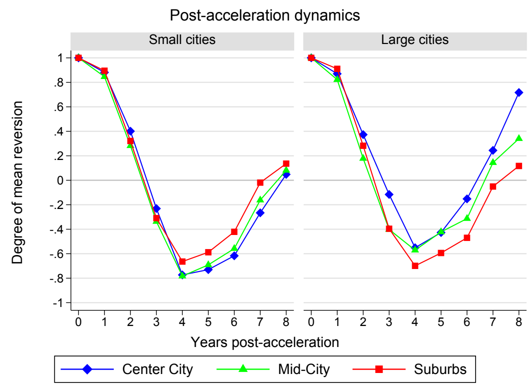
(b) Prior Price Growth



(c) High Regulation



(d) Low Regulation



Note: Dynamic values are calculated by separately estimating regressions of HPI growth from time t to $t+1$ through $t+8$ instead of t to $t+4$. The decline or growth panels correspond with columns 4 and 5 in Table 1 while high and low regulation relate to columns 2 and 3 in Table 3.

years in Table 1. To provide a fuller picture of post-acceleration dynamics, we estimate how real house prices adjust in each subsequent year (e.g. one year later, two years later, etc.) after an acceleration episode. We recover the βs in these regressions and construct a time series of the degree of mean reversion for each subsequent year after an acceleration episode.

Price dynamics are shown in Figure 5 for different levels of housing market regulation and whether real house prices were increasing or decreasing prior to the acceleration. Several additional findings stand out from these figures. First, mean reversion has a consistent ordinal relationship with distance to the CBD within large cities at virtually all time horizons. Second, the trough of prices occurs in years four or five in all areas of all cities. Finally, differences between CBD and suburban dynamics are most apparent in large cities.

5 Conclusion

We identify substantial real house price growth accelerations in over 4,000 ZIP codes in the United States between 1975 and 2015. This paper produces new generalizable results about local house price cycles. The findings make a unique contribution by uncovering variations in house price cycles within cities and showing their post-acceleration dynamics.

There are several stylized facts related to local acceleration episodes. Price accelerations exhibit temporal clustering and are more frequent in large cities. We identify four periods over the last 40 years when extraordinary accelerations occur on a wide scale: the private equity boom of the late 1980s, the "dot-com" boom of the late 1990s, the subprime boom of the mid 2000s, and the oil boom of the early 2010s. While California, Florida, and New England accelerate in all four periods, most areas accelerate in only one or two episodes, such as the Pacific northwest in the late 1980s and oil-producing areas in the early 2010s.

We also explore dynamics following a period of acceleration. Following several years of acceleration, declines in prices tend to occur everywhere. The centers of large cities and areas in a state of long-run economic decline are most resilient to price corrections. Small cities, suburbs of large cities, and low-regulation areas are most vulnerable. These results are consistent with a dynamic, rational expectations model where sustained, high prices are unusual for areas with high supply elasticity. Our findings are also consistent with Edlund, Machado, and Sviatchi's (2015) finding of a steepening house value gradient and Bogin, Doerner, and Larson's (2016) observation of steepening house price gradients in large cities between 1975 and 2015. These facts, in turn, are potentially symptomatic of increased traffic congestion in large cities due to an increase in the number of housing units outpacing transportation network improvements.

When preceded by declining prices, an acceleration results in a price level that is more sustainable than one where the acceleration was preceded by moderate growth. This reinforces concepts of long-run mean reversion common in empirical equilibrium correction models in supply elastic areas (i.e., in the suburbs of large cities and all areas of small cities) but not in the center-cities of large cities. These results therefore call into question the use of rent-price ratio, income-price ratio, or long-run trend analysis for predicting house price paths in areas near the centers of large cities.

Overall, our results indicate that initial accelerations, while perhaps overshooting, may be representative of a positive change to a local area's fundamentals. While supply, demand, and price dynamics can give a bumpy road to the new equilibrium, it appears a new housing market equilibrium with higher prices and/or quantities is, in fact, reached.

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