Shifting House Price Gradients: Evidence Using Both Rental and Asset Prices

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Abstract

Alonso (1964), Mills (1967) and Muth (1969) formalize the monocentric standard urban model (SUM) and demonstrate that price and density gradients characterize differences in urban structure. Subsequent literature concentrated on changes in the population density or the housing asset price gradients. The rental price gradient has been ignored. This paper adds to the literature by providing direct evidence documenting shifts of the house price gradients for both the owner-occupied market and the rental market. The asset price gap between the center city and the suburbs stayed relatively stable before2000 but expanded afterwards. The rental and asset price gradients are found to behave differently over the 1985 to 2013 period studied. Curiously, the slope of the rental and asset price gradients have not moved in parallel over the full sample period. Possible reasons for the steepening of house price gradient are then developed using the standard urban model (SUM) and tested empirically. Asset price gradient steepening is positively associated with the rising congestion cost and dwelling age. In the rental market, MSAs with larger housing units and higher income tend to have a smaller rental price gap between the center city and the suburbs.

Keywords: house price gradient, house price indices, urban structure change, housing market

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1. Introduction

Alonso (1964), Mills (1967) and Muth (1969) formalize the monocentric urban spatial structure model demonstrating that gradient functions for prices and density be used to characterize spatial structure and sprawl. The literature on city spatial structure change was initially based on changes in the population density gradient. Mills (1972), Mieszkowski et. al. (1993), Glaeser and Kahn (2004) and many others have used estimates of the changing population density gradient to measure the American suburbanization. Various possible causes of sprawl have been identified, including unpriced traffic congestion (Anas and Rhee, 2006), availability of roads and highways (Anas and Pines, 2008), low crime rate and quiet neighborhoods in the suburbs (Couch and Karecha, 2006), change of age and household structure (Jaeger and Schwick, 2014), and the improvement of economic base (Brueckner and Helsley 2011). It is debatable whether urban expansion is "purely in response to fundamental forces" or due to some market failures that "may distort their operation … and justifying criticism of urban sprawl" (Brueckner 2000). Although there is lack of agreement on cause, the effect being studied for many years was the determinants of falling population density gradients, or sprawl.

Recent evidence suggests a reversal in the process of sprawl. Center cities are gaining population. Urban research has turned to explaining the revival of the city. There is evidence suggesting that center city housing is becoming more expensive and popular among the highly educated younger generations. Almost all large American cities have experienced large increases in young professionals near CBD since 2000 (Couture and Handbury 2016), and millennials as the creative class prefer living in center cities (Florida 2002). Great divergence of jobs, income, retail services and amenities start to emerge in big cities (Moretti 2012, Diamond 2016). Edlund et al. (2016) argue that gentrification is a result of longer working hours of households as workers favor proximity to work and city amenities more than large housing space because they spend less time at home. As this paper is written, the pandemic may be changing these preferences and relative time allocation between workplace and home.

With more housing transaction data available, the study of urban spatial structure change has most recently switched from population density to changes in the housing asset price gradient. This has the further advantage that the price gradient is not altered by zoning or topographic restrictions. Glaeser, Gottlieb, and Toibo (2012) found that, within metropolitan areas, median house value grew faster in neighborhoods closer to the center city. Bogin et. al. (2018) report larger house price appreciation in areas closer to the city center within large cities. Their work provides the first direct evidence documenting the steepening of the within-city house price gradient. However, most of the estimates struggle with the problem of differentiating between home value changes and changes in the price of housing services. Moreover, the rental price gradient has been ignored although most center city housing is rental in the largest cities.

This paper adds to this literature by providing direct evidence of the housing price gradient shifts using both asset price from the owner-occupied market and the rental prices from the rental market. With publicly available data that covers a wide range of metropolitan areas in the U.S. over a 30 year period, the American Housing Survey (AHS) contains comprehensive and publicly available information on asset and rental prices as well as physical and neighborhood characteristics. This detailed information facilitates the construction of panel data sets of asset and rental price indices in the center cities and the suburbs of large cities. The relative price changes between the center city and the suburb reflects the shift of asset price and rental price gradients over time. Findings on the city spatial structure change are presented from the perspective of both the owner-occupied market and the rental market on a disaggregated geographic level.

The two most commonly used asset price indices in the existing literature are the Case-Shiller home price indices and the FHFA house price indices. Both are generated using the repeat-sales estimates, and they are highly correlated. This paper adda rental price indices. Price indices of both the owner-occupied market and the rental market are constructed using publicly available datasets. Various models are developed to create comparable house price indices. Each model produces a panel of house price indices for the center city and the suburbs for 76 MSAs over 1985-2013. The slope of house price gradient is characterized by the ratio of price in the center city to that in the suburbs, and the difference in the rate of price appreciation between the center city and the suburbs. The indices created using these three models are consistent over time.

Tests based on these new house price indices illustrate three main stylized facts for the owner-occupied market and the rental market respectively. For the owner-occupied market, there is an overall steepening of the asset price gradient over 1985-2013. The asset price gap between the center city and the suburbs stayed relatively stable during the 1980s and 1990s, but it increased after 2000. The shift of the asset price gradient is more significant in MSAs that initially had small populations, low numbers of housing units, and dense structure. However, the rental market does not exhibit comparable rotation in its price gradient over the full sample period. The slope of the rental price gradient mainly increased before the early 1990s, and has stayed stable since then. Furthermore, the pattern of rental price gradient shifts are relatively consistent across MSAs, regardless of the initial condition of population and housing structure characteristics.

The reminder of the essay proceeds as follows. The next section reviews related literature. Section three outlines how the relative asset price and rental price indices between the center city and the suburbs are constructed and compares them to existing house price indices. Section four discusses the stylized facts from the indices, which is followed by the theoretical framework of the standard urban model (SUM) in Section five. Section six demonstrates the results of the empirical tests, and explains the steepening of house price gradients using SUM. The final section concludes with a summary and implications.

2. Literature Review

Alonso (1964), Mills (1967) and Muth (1969) formalize the monocentric urban spatial structure model. Brueckner (1987) presents a unified treatment of the Muth-Mills model and shows that the price per square foot of housing p drops with the distance to CBD and that this rate is a function of commuting cost per round-trip mile and household consumption of housing, which is affected by some exogenous factors. Given usual assumptions about housing production and transportation congestion, the house price gradient follows a negative exponential. Furthermore Bertrand and Brueckner (2005) show that the price gradient maintains its shape in the face of planning restrictions on building height and density.

The literature on city spatial structure change was initially based on changes in the population density gradient. Mieszkowski and Smith (1991) analyzed the decentralization in the

Houston region using estimations of population density functions based on land areas actually used for residential activities. Glaeser and Kahn (2004) use estimates of the changing population density gradient to measure the American suburbanization, and claim that sprawl, as the result of car-based lifestyle, is associated with significant improvements in quality of living. Various possible causes of sprawl have been identified, including unpriced traffic congestion (Anas and Rhee, 2006), availability of roads and highways (Anas and Pines, 2008), low crime rate and quiet neighborhoods in the suburbs (Couch and Karecha, 2006), change of age and household structure (Jaeger and Schwick, 2014), and the improvement of economic base (Brueckner and Helsley 2011). It is debatable whether urban expansion is "purely in response to fundamental forces" or due to some market failures that "may distort their operation … and justifying criticism of urban sprawl" (Brueckner 2000). Although there is lack of agreement on cause, the effect being studied for many years was the determinants of falling population density gradients, or sprawl.

With more housing transaction data available, the study of urban spatial structure change has most recently switched from population density gradients to changes in the housing asset price gradient. Glaeser, Gottlieb, and Toibo (2012) found that, within metropolitan areas, median house value grew faster in neighborhoods closer to the center city. Bogin et. al. (2018) report larger house price appreciation in areas closer to the city center within large cities. Their work provides the first direct evidence documenting the steepening of the within-city house price gradient. The relative house price between center cities and the suburbs is associated with various factors. Guerrieri, Hartley, and Hurst (2013) document dynamics of house price appreciations across neighborhoods in response to city-wide housing demand shocks and explain the endogenous gentrification mechanism as an important determinant of the house price change variation. Edlund, Machado and Sviatchi (2015) found that the rotation of house price gradient is due to the increase in high-skilled workers whose leisure time has shrinked and the improved public safety in the center city. Larson and Zhao (2017) showed the house price gradient rotates and levels up with an oil price change theoretically and empirically. Couture and Handbury (2019) found that the urban revival and rising house price in center cities are driven by the increase in the college-educated population in large cities due to their preference over non-tradable city service amenities.

3. Construction of House Price Gradient Indices

The American Housing Survey (AHS) started in 1973 and is now conducted every other year. The AHS changed the narrative of the questionnaires significantly in 1983, and took away individual household responses on housing value questions in the Public Use File (PUF) starting in2015. As a result, this study uses AHS PUF for 1983-2013. It provides a consistent panel data set of detailed property-level information, including house price (asset price of owner-occupied homes, and rental price of renter-occupied units), housing quality characteristics, geographic location and information on occupants.

There are several major advantages of using AHS data for the purpose of measuring house price changes over space and time. First, AHS covers a large number of housing units in both the owner-occupied and the rental markets. Most center city housing is rental in the largest cities, whereas the rental market has been long ignored in the existing literature on the house price gradient due to data limitations. Second, the AHS provides information of both the housing units that transact and those that did not, therefore reducing the likelihood of sample selection bias. Kiel (1994) found that homeowners were more likely to trade their house if their house had higher-than-average appreciation in the past. This suggests that houses with repeat sales may be fundamentally different from those that are never sold. Third, the panel data feature of AHS makes it relatively easy to control for the quality characteristics of the housing units, hence avoiding the omitted variable bias. Fourth, the rich information of AHS is publicly available. Limited data accessibility due to private listing services has always been a challenge to measure house price changes over a large area and a long period. The AHS public files covers over 100 metropolitan areas over 30 years.

There are two common questions raised concerning the AHS data: the accuracy of self-reported house values, and the lack of objective information on neighborhood characteristics. Goodman and Ittner (1992) found that the average homeowner over-values his/her house by 6%. Kiel and Zabel (2003) found a similar over-valuation of 5.1% and showed that the difference between sales prices and owners' valuations is unrelated to particular characteristics of the house, occupants, or the neighborhood. The missing objective information on the neighborhood and community is not unique to AHS. Given the focus on changes over time, the slow pace of neighborhood change means that the dynamic nature of the measurements here as well as those in repeat sales indexes should not suffer significant bias from this omitted variable.

In this section, a number of house price indices are estimated based on the self-reported asset and rental prices. Case, Pollakowski, and Wachter (1991) and Kiel and Zabel (1997) estimated house price indices for owner-occupied houses by comparing various hedonic models, repeat-sales models, and hybrid models. Both studies found that indices estimated based on the full sample of house values have no substantial differences in the appreciation rates among the various models. However, indices based on subsamples of housing units with sales information have substantial differences in the appreciation rates, which suggests the sample selection bias of the repeat-sales method. For robustness purposes, this study uses a modified repeat-sales method that uses the self-reported values of both the housing units with transaction history and those without over time. It is convenient to refer to the three approaches to estimating house price effects used here as models A,B, and C.

Model A is a standard hedonic regression for asset or rental price, as shown in equation (1). $Y_{i,t,c,m}$ is the asset or rental price (depending on the tenure status) of housing unit *i* at year *t* in the area of *c= center city, suburb* in MSA *m*. $\alpha_{c,m}$ is the location-specific constant term. $X_{i,t,c,m}$ is a vector of housing quality characteristics, including the number of living units, housing unit structure type, number of bedrooms, number of full bathrooms, number of half bathrooms, whether a garage is included, whether a basement is included, the type of air system, the type of heating system, age of the structure and the square of age, interior space of the housing unit in square foot, and the lot size. $D_{j,t,c,m}$ is the year dummy variable with the value of 1 when *j=t* and 0 otherwise. And $\varepsilon_{i,t,c,m}$ is the error term. $\gamma_{j,c,m}$ measures the location-specific asset or rental price appreciation. The average annual appreciation rate of the house price index is calculated in equation (2).

$$Model\ A:\ log(Y_{i,t,c,m}) = \alpha_{c,m} + X_{i,t,c,m}\beta_{c,m} + \sum_{j=2}^{T} D_{j,t,c,m}\gamma_{j,c,m} + \varepsilon_{i,t,c,m} \tag{1}$$

$$\%\Delta HPI = [exp(\tfrac{\hat{\gamma}_t - \hat{\gamma}_{t-1}}{2}) - 1] \tag{2}$$

Model B is a modified repeat-sales model. The traditional repeat-sales method applies to housing units that have been traded without major changes in housing quality characteristics during the sample period. The AHS contains self-reported values of all the sampled housing units regardless of the transaction history. Controlling for the housing quality characteristics, this repeat-value model, as shown in equation (3), is applied over all houses to estimate the rate of housing price appreciation. There are 73,456 owner-occupied housing units and 39,202 rental units over 76 MSAs included in this repeat-value model, which is fewer than the 177,126 owner-occupied units and 130,280 rental units in the previous standard hedonic model, because houses that were surveyed only once during the sample period are dropped, as well as the units with changes in housing quality characteristics.

$$Model\ B:\ \Delta logY_{i,t,t-1} = \sum_{j=2}^{T} \Delta D_{j,t,t-1}\gamma_j + \Delta\varepsilon_{i,t,t-1} \tag{3}$$

, where the first differenced variables are constructed as

$$\Delta logY_{i,t,t-1} \equiv log(Y_{i,t,c,m}) - log(Y_{i,t-1,c,m}) \tag{4}$$

$$\Delta D_{j,t,t-1} \equiv D_{j,t,c,m} - D_{j,t-1,c,m} \tag{5}$$

$$\Delta\varepsilon_{i,t,t-1} = \varepsilon_{i,t,c,m} - \varepsilon_{i,t-1,c,m} \tag{6}$$

If houses that had changes in housing quality characteristics are different from those that had none, house price indices estimated using the repeat-value model can be biased. And the repeat-value model does not allow the impact of time to be separated from that of building age. This problem can be avoided using a hybrid model, by taking first differences using Equation (1) to include changes in housing quality characteristics.

$$Model\ C:\ \Delta logY_{i,t,t-1} = \Delta X_{i,t,t-1}\beta + \sum_{j=2}^{T} \Delta D_{j,t,t-1}\gamma_j + \Delta\varepsilon_{i,t,t-1} \tag{7}$$

Appendix A1-A2 shows the number of housing units in the center city and the suburbs of each MSA when the above models are used to estimate asset and rental price appreciation indexes for the owner-occupied and rental markets respectively. The location of center city or suburb is defined directly by the AHS while the MSA borders follow the 2013 metropolitan map definition. Each model produces a panel of house price indices of the center city and the suburbs for about 76 MSAs over 1985-2013 (base year = 1985), using asset and rental prices for owner-occupied market and rental market respectively. The slope of house price gradient is measured both by the relative price between the center city and the suburbs, and the absolute difference in price appreciation between the center city and the suburbs.

It is informative to compare the asset price indexes that are created using AHS here with alternative indexes in the literature. The two most commonly used asset price indices in the existing literature are the Case-Shiller home price indices and the FHFA house price indices. Both are created using the repeat-sales method for the owner-occupied market. The models discussed in the previous part generate three panels of MSA-level house price indices, using hedonic estimation, repeat-sales method and modified repeat-sales method. Figure 1 illustrates the comparisons among the appreciation rates of the national level house asset price indices created based on: (1) standard hedonic model, (2) repeat-value model, (3) hybrid model, (4) Case-Shiller national home price indices, and (5) FHFA house price indices.

Casual observation suggests that house price appreciation rates based on repeat sales indices are biased upward. The mean of the annual asset appreciation rates over the sample period is 3.5% based on Case-Shiller HPI and FHFA HPI, with the max of 10% and 13% in 2005 and the min of -5% and -9% in 2009, respectively. The mean of the asset price appreciation rates based on data constructed in this paper using AHS are: (1) standard hedonic model: -0.2% in the center city and -0.3% in the suburbs, (2) repeat-value model: -1.9% in the center city and suburbs, (3) hybrid model: -0.8% in the center city and -0.5% in the suburbs. In terms of the variance of the annual asset appreciation rates, FHFA HPI appreciation rates has the lowest variance of 0.17%, while Case-Shiller HPI appreciation rates have the largest variance of 0.33%. The three models based on AHS indices have variances ranging from 0.18% to 0.31%, in line with the two repeat sales indices. As predicted in the literature, higher appreciation promotes more sales. Kiel (1994) found that homeowners were more likely to trade their house if their house had higher-than-average appreciation in the past.

To better understand the stationary of the annual average appreciation rates of the above five house price indices, augmented Dickey-Fuller regressions (ADF1981) are estimated for each series. Tests are based on ADF with 0-2 lags, a constant term and no trend. Following Bogin, Doerner and Larson (2019), a deterministic constant term is included but not a trend because "it is difficult to justify a model with real house prices trending upward ad infinitum." ADF tests results are shown in Table 1. The null hypothesis of a unit root can be rejected at 90% level for all. The house price appreciation rates based on various data sources and models are stationary and predictable.

The Engle-Granger two-step tests for cointegration are then conducted between each pair of two house price indices appreciation rates. The cointegrating residuals are examined using ADF with 1 lag, a constant term and no trend term. As shown in Table 2, the null hypothesis of the ADF tests that the residuals have a unit root can be rejected in all pairs, which provides evidence in support of the cointegration of the house price appreciation rates constructed by

FHFA HPI, Case-Shiller Home Price indices and AHS asset price indices based on standard hedonic model, repeat value model and hybrid model.

Tests for structure breaks show that the annual average real appreciation rates of all house price indices have similar pattern over time: FHFA HPI and Case-Shiller Home Price Indices have structural breaks in 2005 and 2009. The AHS asset price indices based on the three models mentioned in the previous part have structural breaks in 2003 and 2011.

As a comparison to the appreciation rates of the owner-occupied market, national level rental price indices are created using the number of MSA-level housing units as weights. The three models discussed in Equations (1)-(7) produce three sets of annual average real appreciation rates of national rental price indices, as shown in Figure 2. In model A, B, and C, the mean of the annual rental price appreciation rates in center city over the full sample period is 0.5%, 1.6%,and 1.1% respectively. Those in the suburbs are 0.2%, 0.2%, and 0.4%. From 1987 to late 1990s, the rental market in the center city had consistent higher appreciation rates than the suburban market did. Over 1987-1999, the annual rental price appreciation rates in the center city is, on average, 0.4% - 1.5% higher than those in the suburbs based on the three models. However, since 2000, the center city rental market showed signs of leading the suburban market in terms of the movement of the appreciation rates.

ADF regressions are estimated for annual appreciation rates for each of the rental price indices. Tests are based on ADF with 0-2 lags, a constant term and no trend. As shown in Table 3, the null hypothesis of a unit root is rejected in all models. The appreciation rates of rental price indices generating using AHS based on the three models are all stationary and predictable. The Engle-Granger two-step tests for cointegration are then conducted between each pair of two house price indices appreciation rates. The cointegrating residuals are examined using ADF with 1 lag, a constant term and no trend term. Results of the ADF tests on the residuals are shown in Table 4, and provide statistical evidence in support of the cointegration of the rental price appreciation rates based on the AHS rental price indices using various models.

Table A3 and Table A4 demonstrate the summary statistics of the house price appreciation indices created using the standard hedonic model, the repeat-value model and the hybrid model. The three sets of panel datasets have similar patterns. Among the three, the standard hedonic model and the hybrid model produce very consistent results.

4. Stylized Facts Regarding Shifting House Price Gradients

This section examines the shift of asset and rental price gradients over time following the framework of SUM. Instead of finding the house price at every location in the city and tracing out the entire house price gradient for each of the years in the sample period, this paper tests the changes of the slope of house price gradients on the owner-occupied market and rental market respectively.

$$(P_{center}/P_{suburb})_{t,m} = (P_{center}/P_{suburb})_{t-1,m} * \left(\frac{1+\%\Delta HPI_{center}}{1+\%\Delta HPI_{suburb}}\right)_{t-1,t,m} \tag{8}$$

The slope of house price gradient in MSA *m* at year *t* is proxied by the relative price between the center city and the suburbs, $(P_{center}/P_{suburb})_{t,m}$. The change of the house price gradient slope is measured by the relative gross appreciation rate between the center city and the suburbs, $\left(\frac{1+\%\Delta HPI_{center}}{1+\%\Delta HPI_{suburb}}\right)_{t-1,t,m}$. When this ratio of gross appreciation rates is greater than 1, $\left(\frac{1+\%\Delta HPI_{center}}{1+\%\Delta HPI_{suburb}}\right)_{t-1,t} > 1$, or when the rate of house price appreciation is larger in the center city than in the suburbs, $\%\Delta HPI_{center,\, t-1,t} > \%\Delta HPI_{suburb,\, t-1,t}$.

The tests in rest of this study mainly are mainly based on the house price indices generated using the standard hedonic model. The three sets of house price indices based on the standard hedonic model, repeat-value model and the hybrid model are highly consistent and correlated, however, the standard hedonic model has the largest sample size.

Over the entire sample period, 36 out of 76 MSAs had larger asset appreciation rates in the center city than in the suburbs. When MSAs are divided into halves based on the number of housing units in 2013, there are 22 large MSAs and 14 small MSAs that experienced the steepening of asset price gradient over 1985-2013. In order to examine the timing of changes in asset price gradients, the entire sample period is divided into seven four-year windows: 1985-2013, 1985-1989, 1989-1993, 1993-1997, 1997-2001, 2001-2005, 2005-2009 and 2009-2013. Figure 3 lists the number of MSAs by whether its asset appreciation rate is larger in the center city than in the suburbs, and whether its number of housing units is larger than the national median. The fraction of MSAs that experienced the steepening of asset price gradient remained relatively stable during each of the subperiods.

Similarly, the rental markets are examined over the full sample period and during each of the four-year subperiods, based on whether the rental price appreciation rate is larger in the center city than in the suburbs, and whether the rental housing market is larger than the national median. A summary of the fractions is demonstrated in Figure 4. The steepening of rental price gradient is strongest in 1989-1993.

To examine if there is a persistent time trend of the change in the slope of house price gradients, tests are conducted using equation (9). The ratio of house price indices between the center city and the suburb in year t in MSA m, $(P_{center}/P_{suburb})_{t,m}$, is calculated as the relative house price estimates based on the standard hedonic model, using asset price for the owner-occupied market and the rental price for the rental market respectively. The time trend variable $year_t$ is coded with the year 1985 as 0, year 1987 as 2, and so on so forth until year 2013 as 28. This is because AHS is conducted every other year. MSA_m is the metropolitan area fixed effect, and $\varepsilon_{t,m}$ is the error term. The recent evidence of center cities gaining population suggests a positive β and hence an increase in the slope of both asset price and rental price gradients over time. But such population shifts could reflect zoning changes rather than price shifts.

$$(P_{center}/P_{suburb})_{t,m} = \alpha + \beta * year_t + MSA_m + \varepsilon_{t,m} \quad (9)$$

The above equation is first tested during the sample period 1985-2013 over 76 MSAs, to examine the time trend of the asset price ratio changes. As suggested by the discussion in previous sections, the changes in the slope of asset price gradients have different patterns over various time periods. The relative growth of asset price indices between the center city and the suburbs was stable before 2000, and the growth gap has grown during the 2000s. Regressions based on equation (9) are further tested on sub time periods of 1985-1999 and 1999-2013, as well as over each decade (or so) of 1985-1993, 1993-2003, and 2003-2013.

The results are shown in Table 5. The slope of the asset price gradient across the US is becoming 0.2% steeper annually starting from the initial price ratio of 0.971 in 1985. Overall, it became 6% steeper over the three decades between 1985 and 2013. The reversal of the asset price gradient slope is mainly driven by the relative asset price changes since 2000. The time trend of the asset price gradient rotation is 0.006 per year after 2000 (about 0.7% steeper annually compared to the initial slope), or about 1.2% steeper annually compared to the initial slope. The regression results also provide evidence of the relative stability of the asset price gradient in the 1980s and 1990s.

The rental market behaved differently during the sample period. Table 6 shows the time trend of the ratio of rental price indices between the center city and the suburbs generated based on the standard hedonic model over the full sample time period and during various sub periods. The slight steepening of rental price gradient happened during the 1980s and 1990s and stopped afterwards. When the sample is divided into halves, the ratio of rental price indices between the center city and the suburbs was increasing by 0.3% per year before 2000. The relative rental price indices increased even faster during the first decade, at the rate of 0.7% annually.

Table 7 shows the results of tests to determine if the owner-occupied and the rental markets had the comparable shifts. Compared to the rental market, the owner-occupied market started from a lower price ratio between the center city and the suburbs, and steepened at a faster rate during 1985-2013 overall. However, the shift of rental price gradient is significantly larger than that of the asset price gradient before 1999, especially during the first decade of the sample period. Whereas the steepening of the asset price gradient is more prominent since the 2000s.

In sum, tests on the house price indices generated in this study present three main stylized facts for the owner-occupied market and the rental market respectively. For the owner-occupied market, there is an overall steepening of the asset price gradient over 1985-2013. The asset price gap between the center city and the suburbs stayed relatively stable during the 1980s and 1990s, but it expanded increasingly post 2000. Such rotation of the asset price gradient is more significant in MSAs that initially had small populations, low housing stock, and dense structure.

However, the rental market did not exhibit comparable rotation over the full sample period. The slope of the rental price gradient mainly increased before the early 1990s, and has stayed stable since then. And the pattern of rental price gradient shifts are relatively consistent across MSAs, regardless of the initial condition of population and housing structure characteristics. These results add to the literature by providing direct evidence on the shift of asset and rental price gradients within and across MSA, and support the recent studies on the city spatial structure change.

5. SUM and the House Price Gradient Shift

The study on the shift of house price gradients is directly based on the Standard Urban Model (SUM). Brueckner (1987) presents a unified treatment of the Muth-Mills model and shows that the price per square foot of housing p drops with distance k to CBD and that this rate is a function of commuting cost per round-trip mile t and household consumption of housing h, which is affected by some exogenous factors σ.

$$\frac{\partial p}{\partial k} = -\frac{t}{h(k;\sigma)} \qquad (10)$$

A large body of literature has discussed various potential determinants of the shift of the house price gradients. Anas and Rhee (2006) and Anas and Pines (2008) examined unpriced traffic congestion leads to inefficient urban sprawl. Couch and Karecha (2006) discussed how low crime rate and quiet neighborhoods in suburbs affect households' location choice and thus the house price change. Glaeser, Kahn and Rappaport (2008) found that the housing-based force is weaker than the time-cost force, resulting in high-income households' location choice in the center cities. Brueckner and Rosenthal (2009) discussed how the age of the housing stock affects the location of high- and low-income neighborhoods in the US and hence the gentrification. Jaeger and Schwick (2014) discussed several explanations on the shift of house price gradient, such as change in life-style, household structure, and employment structure, in addition to the traditional explanations that focus on commuting behavior and income. Brueckner and Helsley (2011) identified the improvement of economic base as a potential determinant of the house price gradient change. Edlund, Machado and Sviatchi (2015) found that the rotation of house price gradient is due to the increase in high-skilled workers whose leisure time has shrinked and the improved public safety in the center city.

This section presents a model that is based on SUM and in line with the literature. In a monocentric city, households consume housing h and a composite commodity c, and commute to CBD for employment. Households earn the same base income y. Following Brueckner and Rosenthal (2009), Housing services depend on the dwelling's age a and some exogenous factors α, with $h = h(a(k);\sigma)$ and $h_a < 0$. For workers, the time cost of commuting is a fraction of the full work time income. Total commuting cost per unit distance k is the sum of the out-of-pocket cost t and the opportunity cost of commuting time ϕy. The household's utility maximization problem becomes

$$max\ U(c,h) \text{ s.t. } y = c + p(k)h(a(k);\sigma) + T(k) \text{ and } T(k) = (t+\phi y)k \tag{11}$$

The house price gradient is implicitly defined by the indirect utility function

$$V[y - p(k)h(a(k);\sigma) - (t+\phi y)k,\ h(a(k);\sigma)] = u \tag{12}$$

Total differential w.r.t the distance k and first order condition give

$$p_k = -\frac{t+\phi y}{h(a(k);\sigma)} \tag{13}$$

$$\frac{\partial p_k}{\partial t} < 0,\ \frac{\partial p_k}{\partial \phi} < 0 \tag{14}$$

$$\frac{\partial p_k}{\partial a} = \frac{t + \phi y}{h(a(k);\sigma)^2} h_a < 0 \quad (15)$$

$$\frac{\partial p_k}{\partial y} = \frac{(t+\phi y) h_\sigma \sigma_y}{h(a(k);\sigma)^2} - \frac{\phi}{h(a(k);\sigma)} \quad (16)$$

$$\frac{\partial p_k}{\partial \sigma} = \frac{(t+\phi y)}{h(a(k);\sigma)^2} h_\sigma \quad (17)$$

This model presents several testable predictions. First, both out-of-pocket cost of commuting and traffic congestion delay are positively correlated with a larger price gap between the center city and the suburbs. Second, places with older housing tend to have steeper house price gradients. Third, the effect of income on the shift of house price gradient is ambiguous. Rising income increases the time cost of commuting. However the income elasticity is less than one, suggesting richer households will lower their housing consumption share and live in the suburbs. Finally, the effect of exogenous factors σ on the house price gradient varies, depending on how the factor changes households' housing demand specifically.

6. Empirical tests of the ability of SUM factors to explain the house price gradient shifts

To test the predictions stated above, equation (18) is specified and estimated. The dependent variable is the ratio of AHS house price indices between the center city and the suburbs in year t in MSA m, created based on the standard hedonic model from the previous section. $year_t$ is the time trend with $1985 = 0,\ 1987 = 2,\ ...,\ 2013 = 28$. $X'_{t,m}$ is a set of covariates, including city congestion cost and delay time, city income, dwelling age, housing structure density, household size, and land supply and regulation index. MSA_m is the metropolitan area fixed effect, and $\varepsilon_{t,m}$ is the error term.

$$(P_{center}/P_{suburb})_{t,m} = \alpha + \beta * year_t + X'_{t,m}\gamma + MSA_m + \varepsilon_{t,m} \quad (18)$$

City congestion cost and delay time are generated using the Urban Mobility Scoreboard constructed by Texas A&M Transportation Institute. It provides a panel dataset of annual total congestion cost per commuter generated based on travel delay time, value of time per auto commuter, gas cost, and wasted fuel over 101 urban areas from 1982 to 2017. City income is measured as the MSA-level per capita personal income computed by the Bureau of Economic Analysis (BEA). Dwelling age variables are the weighted average age of housing units using the sampling weights from AHS, and the difference between the MSA-level and national average dwelling age. Housing structure variables include the weighted average interior housing space, the difference between MSA-level and national average interior housing space, share of housing units in a building with more than 10 units, and the difference between MSA and national share of buildings with more than 10 units. The final data set contains 53 MSAs over 1985-2013.

Table 8 presents the relation between the rotation of asset price gradient and covariates based on SUM over 1985-2013. For the owner-occupied market, congestion cost is significant and positively correlated with the relative asset price between the center city and the suburb. The slope of the asset price gradient shifts positively with the MSA average dwelling age, and negatively with the quadratic term, suggesting a non-linear relation. These results are consistent with the predictions of the Muth-Mills equation.

Results for the rental market are shown in Table 9. Rising income is associated with higher relative rental price between the center city and the suburbs, suggesting the effect of income on increasing time cost of commuting is stronger than that on renters' demand for housing. Interior housing space is negatively correlated with the slope of the rental price gradient. MSAs with larger housing units on average tend to have a smaller rental price gap between the center city and the suburbs. These results echo those in the literature on the rotation of house price gradient and Muth-Mills equation framework.

For robustness tests, Equation (18) is applied to samples pre and post 1999 with the covariates of congestion, income, dwelling age and housing structure. Table 10 and Table 11 present the results on the owner-occupied market over 1985-1999 and 1999-2013 respectively. The effect of congestion cost on the shift of the asset price gradient is significant and positive pre and post 2000, as predicted by SUM. Dwelling age moves positively with the ratio of asset price between the center city and the suburbs over 1999-2013, providing consistent evidence on the renovations and rebuilding in the gentrifying cities. For the rental market, the subperiod regression results are demonstrated in Table 12 and Table 13. Interior housing space reverses the slope of the rental price gradient in both subperiod, as predicted by the Muth-Mills equations.

7. Conclusions

Alonso (1964), Mills (1967) and Muth (1969) formalize the monocentric urban spatial structure model and advocate the gradient approach to analyze the urban structure change and sprawl. Subsequent literature has been based on changes in population density or the slope of the asset price gradient for the owner-occupied market. This paper addresses the price gradient shift in the rental market, which has been ignored in the existing literature, estimates the rotations of the asset and rental price gradients, and brings the recent phenomenon of city revival with the SUM framework.

The contribution of this paper is threefold. First, this paper addresses the gap in the availability of rental price indices by creating a new set of asset and rental price indices. House price indices are created based on the standard hedonic model, the repeat-value model and the hybrid model, using information from American Housing Survey that covers 76 MSAs in the US over 1985-2013. Compared to the mostly used repeat-sales house price indices in the existing literature, AHS provides information of both the housing units that transact and those that did not, therefore reducing the likelihood of sample selection bias. Limited data accessibility due to private listing services has always been a challenge to measure house price changes over a large area and a long period. Whereas AHS public files covers more than 100 metropolitan areas over 30 years.

Second, this paper adds to the literature on city spatial structure change by providing direct evidence documenting the shift of the house price gradients for both the owner-occupied market and the rental market. Tests based on the new house price indices illustrate three main stylized facts for the owner-occupied market and the rental market respectively. For the owner-occupied market, there is an overall steepening of the asset price gradient over 1985-2013. The asset price gap between the center city and the suburbs has stayed relatively stable during the 1980s and 1990s, but it expanded increasingly post 2000. The shift of the asset price gradient is more significant in MSAs that initially had small populations, low housing stock, and dense structure. However, the rental market does not exhibit comparable rotation over the full sample period. The slope of the rental price gradient mainly increased before the early 1990s, and has stayed stable since then. And the pattern of rental price gradient shifts are relatively consistent across MSAs, regardless of the initial condition of population and housing structure characteristics.

Third, empirical tests evidenced in this paper use a specially constructed panel data set of the new house price indices and economic fundamentals, and confirm the relations between the shift of house price gradients and these covariates, as predicted by Muth-Mills equation. For the owner-occupied market, the shift of asset price gradient is positively associated with the rising congestion cost and the MSA average dwelling age. Whereas in the rental market, MSAs with larger housing units on average and higher income tend to have a smaller rental price gap between the center city and the suburbs, suggesting the steepening of the rental price gradient. These results echo the findings in the literature on the rotation of house price gradient and city gentrification. SUM can well explain the empirically observed phenomenon of city revival and gentrification. No other assumptions, which are often made however, are needed, such as different housing preferences of the younger generations and differentiation between city amenities and suburban amenities.

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Tables and Figures

Table 1. Augmented Dickey-Fuller test for unit root			
Annual Average Appreciation Rates of House Price Indices	0 lag	1 lag	2 lags
FHFA HPI	-1.868**	-3.169***	-1.793*
Case-Shiller Home Price Indices	-2.045**	-3.163***	-1.703*
AHS Asset Price Index (standard hedonic model)	-1.445*	-1.420*	-1.910**
AHS Asset Price Index (repeat value model)	-1.321	-1.771*	-2.344**
AHS Asset Price Index (hybrid model)	-1.474*	-1.965**	-2.284**

Note: * t<0.1; ** t<0.05; *** t<0.01. The tests are based on the annual average appreciation rates of the following five house price indices: (1) FHFA HPI, (2) Case-Shiller national home price indices, (3) national asset price index based on standard hedonic model using AHS, (4) national asset price index based on repeat value model using AHS, (5) national asset price index based on hybrid model using AHS. Augmented Dickey-Fuller regressions are estimated for each series during 1987-2013. Models include 0-2 lags, a constant term but no trend term. Z(t) has t-distribution, and the 1%, 5% and 10% critical values tabulated by MacKinnon (1991) are (1) -2.718, -1.796, -1.363 with 0 lag; (2) -2.821, -1.833, -1.383 with 1 lag; (3) -2.998, -1.895, -1.415 with 2 lags.

Table 2. Engle-Granger two-step tests for cointegration					
	Indep. Var.				
Dep. Var	FHFA HPI	Case-Shiller Home Price Indices	AHS Asset Price Index (standard hedonic model)	AHS Asset Price Index (repeat value model)	AHS Asset Price Index (hybrid model)
FHFA HPI		-1.799*	-3.523***	-3.061***	-3.307***
Case-Shiller Home Price Indices	-2.476**		-4.698***	-4.606***	-5.093***
AHS Asset Price Index (standard hedonic model)	-2.378**	-1.905**		-4.875***	-2.243**
AHS Asset Price Index (repeat value model)	-1.879**	-1.529*	-4.398***		-2.817**
AHS Asset Price Index (hybrid model)	-2.366**	-2.264**	-2.315**	-3.041***	

Note: * t<0.1; ** t<0.05; *** t<0.01. The tests are based on the annual average appreciation rates of the following five house price indices: (1) FHFA HPI, (2) Case-Shiller national home price indices, (3) national asset price index based on standard hedonic model using AHS, (4) national asset price index based on repeat value model using AHS, (5) national asset price index based on hybrid model using AHS. Augmented Dickey-Fuller regressions on the residuals of each pair are estimated using models including 1 lag, a constant term but no trend term. Z(t) has t-distribution, and the 1%, 5% and 10% critical values tabulated by MacKinnon (1991) are -2.821, -1.833, -1.383 with 1 lag.

Table 3. Augmented Dickey-Fuller test for unit root			
Annual Average Appreciation Rates of Rental Price Indices	0 lag	1 lag	2 lags
AHS center city (standard hedonic)	-4.301***	-2.792**	-2.015**
AHS center city (repeat value)	-6.340***	-2.836***	-2.234**
AHS center city (hybrid model)	-4.344***	-2.833***	-2.153**
AHS suburb (standard hedonic)	-4.406***	-2.785**	-2.419**
AHS suburb (repeat value)	-3.956***	-2.843***	-1.707*
AHS suburb (hybrid model)	-3.477***	-2.466**	-2.023**

Note: * t<0.1; ** t<0.05; *** t<0.01. The tests are based on the annual average appreciation rates of the following three rental price indices for the center city and the suburbs respectively: (1) national rental price index based on standard hedonic model using AHS, (2) national rental price index based on repeat value model using AHS, (3) national rental price index based on hybrid model using AHS. Augmented Dickey-Fuller regressions are estimated for each series during 1987-2013. Models include 0-2 lags, a constant term but no trend term. Z(t) has t-distribution, and the 1%, 5% and 10% critical values tabulated by MacKinnon (1991) are (1) -2.718, -1.796, -1.363 with 0 lag; (2) -2.821, -1.833, -1.383 with 1 lag; (3) -2.998, -1.895, -1.415 with 2 lags.

Table 4. Engle-Granger two-step tests for cointegration						
	Indep. Var.					
Dep. Var	AHS center city (standard hedonic)	AHS center city (repeat value)	AHS center city (hybrid model)	AHS suburb (standard hedonic)	AHS suburb (repeat value)	AHS suburb (hybrid model)
AHS center city (standard hedonic)		-3.559***	-2.006**		-2.867***	-1.885**
AHS center city (repeat value)	-3.664***		-4.112***	-2.858***		-2.855***
AHS center city (hybrid model)	-1.933**	-4.293***		-3.053***	-3.362***	
AHS suburb (standard hedonic)		-2.690**	-3.394***		-2.758**	-0.976
AHS suburb (repeat value)	-2.752**		-3.164***	-2.636**		-3.804***
AHS suburb (hybrid model)	-1.780*	-2.278**		-1.095	-3.089***	

Note: * t<0.1; ** t<0.05; *** t<0.01. The tests are based on the annual average appreciation rates of the following three rental price indices: (1) national rental price index based on standard hedonic model using AHS, (2) national rental price index based on repeat value model using AHS, (3) national rental price index based on hybrid model using AHS. Augmented Dickey-Fuller regressions on the residuals of each pair are estimated using models including 1 lag, a constant term but no trend term. Z(t) has t-distribution, and the 1%, 5% and 10% critical values tabulated by MacKinnon (1991) are -2.821, -1.833, -1.383 with 1 lag.

Table 5: Time Trend of Asset Price Indices Ratios between Center City and Suburb

Dep. Var.	Asset Price Indices Ratio $(P_{center}/P_{suburb})_{t,m}$					
Sample	1985-2013	1985-1999	1999-2013	1985-1993	1993-2003	2003-2013
Time Trend	0.002*	0.001	0.006*	0.000	0.001	0.010*
	[0.001]	[0.001]	[0.004]	[0.002]	[0.002]	[0.006]
Constant	0.971***	1.015***	0.831***	1.076***	0.926***	0.802***
	[0.013]	[0.009]	[0.083]	[0.007]	[0.021]	[0.130]
R2	0.27	0.45	0.31	0.61	0.54	0.3
N	1,140	608	608	380	456	456

Note: * p<0.1; ** p<0.05; *** p<0.01. This table reports the regression results of the ratio of asset price indices between the center city and the suburbs created based on the standard hedonic model. The main dependent variable is the time trend with year 1985 coded as 0, year 1987 coded as 2, and all the way until year 2013 coded as 28. The sample covers 76 MSAs over 1985-2013 using AHS PUF data. MSA fixed effects are included in all models. Standard errors are adjusted based on clustering at the MSA level.

Table 6: Time Trend of Rental Price Indices Ratios between Center City and Suburb						
Dep. Var.	Rental Price Indices Ratio $(P_{center}/P_{suburb})_{t,m}$					
Sample	1985-2013	1985-1999	1999-2013	1985-1993	1993-2003	2003-2013
Time Trend	0.001	0.003***	0.000	0.007***	-0.002	0.002
	[0.001]	[0.001]	[0.002]	[0.002]	[0.002]	[0.003]
Constant	1.043***	1.000***	1.083***	0.980***	1.107***	1.022***
	[0.012]	[0.009]	[0.037]	[0.010]	[0.022]	[0.077]
R2	0.44	0.62	0.50	0.64	0.63	0.51
N	1,140	608	608	380	456	456

Note: * p<0.1; ** p<0.05; *** p<0.01. This table reports the regression results of the ratio of rental price indices between the center city and the suburbs created based on the standard hedonic model. The main dependent variable is the time trend with year 1985 coded as 0, year 1987 coded as 2, and all the way until year 2013 coded as 28. The sample covers 76 MSAs over 1985-2013 using AHS PUF data. MSA fixed effects are included in all models. Standard errors are adjusted based on clustering at the MSA level.

Table 7: Regression Results on the comparability of the Shift of Asset and Rental Price Gradients						
Dep. Var.	Ratio of House Price Indices between Center City and Suburb					
Sample	1985-2013	1985-1999	1999-2013	1985-1993	1993-2003	2003-2013
Time Trend	0.001	0.003***	0.000	0.007***	-0.002	0.002
	[0.001]	[0.001]	[0.002]	[0.002]	[0.002]	[0.003]
Time Trend * Own	0.001	-0.003	0.006	-0.007**	0.003	0.007
	[0.001]	[0.002]	[0.004]	[0.003]	[0.002]	[0.006]
Own	-0.031*	-0.006	-0.137	0.009	-0.067**	-0.176
	[0.017]	[0.011]	[0.084]	[0.006]	[0.034]	[0.135]
Constant	1.022***	1.010***	1.022*	1.023***	1.050***	1.000***
	[0.013]	[0.007]	[0.047]	[0.006]	[0.025]	[0.071]
R2	0.22	0.32	0.24	0.37	0.34	0.24
N	2,280	1216	1216	760	912	912

Note: * p<0.1; ** p<0.05; *** p<0.01. Regression Are based on the ratio of price indices between the center city and the suburbs created using the standard hedonic model, by pooling the owner-occupied and rental markets. The variable time trend is coded with year 1985 as 0, year 1987 as 2, and all the way until year 2013 as 28. The variable Own is a tenure status dummy variable with owner-occupied units as 1. The sample covers 76 MSAs over 1985-2013 using AHS PUF data. MSA fixed effects are included in all models. Standard errors are adjusted based on clustering at the MSA level.

Table 8: Shift of Asset Price Gradient and Muth-Mills Equation Variables 1985-2013					
Dep. Var.	Asset Price Ratio				
	(1)	(2)	(3)	(4)	(5)
time trend	-0.0040**	-0.0013	0.011	0.0083	-0.0051
	[0.0017]	[0.0021]	[0.0134]	[0.0083]	[0.0098]
delay cost	0.0963*				0.1169**
	[0.0500]				[0.0441]
delay cost * time trend	0.0028*				0.0024*
	[0.0014]				[0.0014]
income		-0.0045			-0.0002
		[0.0047]			[0.0041]
income * time trend		0.0002*			0.0000
		[0.0001]			[0.0001]
dwelling age			0.0198*		0.0255*
			[0.0113]		[0.0154]
dwelling age^2			-0.0002*		-0.0001
			[0.0002]		[0.0002]
dwelling age * time trend			-0.0008		0.0002
			[0.0007]		[0.0005]
dwelling age^2 * time trend			0.0000		-0.0000
			[0.0000]		[0.0000]
interior space				0.0117	0.0185
				[0.0287]	[0.0146]
interior space * time trend				-0.0034	-0.0037*
				[0.0038]	[0.0020]
buildings with 10+ units				-0.4156	-0.2230
				[0.4168]	[0.3330]
buildings with 10+ units * time trend				0.0183*	0.0026
				[0.0104]	[0.0139]
constant	0.9875***	1.0709***	0.5436**	0.9517***	0.8473***
	[0.0181]	[0.0766]	[0.2467]	[0.0642]	[0.2847]
R2	0.34	0.24	0.28	0.28	0.35
N	825	1,004	1,139	1,139	824

Note: * p<0.1; ** p<0.05; *** p<0.01. This table reports the regression results of the ratio of asset price indices between the center city and the suburbs created based on the standard hedonic model. Time trend is coded with 1985 = 0, 1987 = 2, ..., 2013 = 28. Delay cost is the annual total delay cost per commuter (1000$) as the sum of travel gas cost and congestion time cost, generated using the Urban Mobility Scoreboard constructed by Texas A&M Transportation Institute. Income is the per capita personal income (1000$) released by the Bureau of Economic Analysis (BEA). Dwelling age is the MSA weighted average dwelling age using the housing sampling weight from AHS. Interior space is the weighted average interior housing space (1000 sqft) based on the AHS sampling weights. Buildings with 10+ units is the percent of sampled housing units that are in buildings with 10+ units. MSA fixed effects are included in all models. Standard errors are adjusted based on clustering at the MSA level.

Table 9: Shift of Rental Price Gradient and Muth-Mills Equation Variables 1985-2013					
Dep. Var.	Rental Price Ratio				
	(1)	(2)	(3)	(4)	(5)
time trend	.0003	0.0030	0.0120	0.0004	0.0019
	[0.0023]	[0.0021]	[0.0081]	[0.0034]	[0.0071]
delay cost	-0.0173				-0.201
	[0.0417]				[0.0393]
delay cost * time trend	0.0001				0.0004
	[0.0016]				[0.0017]
income		0.0024*			0.0045*
		[0.0015]			[0.0023]
income * time trend		-0.0001*			-0.0001
		[0.0000]			[0.0001]
dwelling age			-0.0143*		0.0042
			[0.0080]		[0.0091]
dwelling age^2			0.0002*		-0.0001
			[0.0001]		[0.0001]
dwelling age * time trend			-0.0002		-0.0000
			[0.0004]		[0.0003]
dwelling age^2 * time trend			0.0000		-0.0000
			[0.0000]		[0.0000]
interior space				-0.0249*	-0.0161**
				[0.0152]	[0.0079]
interior space * time trend				-0.0003	-0.0012
				[0.0020]	[0.0016]
buildings with 10+ units				0.0967	-0.0757
				[0.1877]	[0.1068]
buildings with 10+ units * time trend				0.0019	-0.0042
				[0.0050]	[0.0067]
constant	1.0562***	0.9934***	1.3123***	1.0002***	0.9748***
	[0.0185]	[0.0383]	[0.1696]	[0.0534]	[0.2038]
R2	0.44	0.41	0.45	0.45	0.45
N	825	1,004	1,139	1,139	824

Note: * p<0.1; ** p<0.05; *** p<0.01. This table reports the regression results of the ratio of rental price indices between the center city and the suburbs created based on the standard hedonic model. Time trend is coded with 1985 = 0, 1987 = 2, ..., 2013 = 28. Delay cost is the annual total delay cost per commuter (1000$) as the sum of travel gas cost and congestion time cost, generated using the Urban Mobility Scoreboard constructed by Texas A&M Transportation Institute. Income is the per capita personal income (1000$) released by the Bureau of Economic Analysis (BEA). Dwelling age is the MSA weighted average dwelling age using the housing sampling weight from AHS. Interior space is the weighted average interior housing space (1000 sqft) based on the AHS sampling weights. Buildings with 10+ units is the percent of sampled housing units that are in buildings with 10+ units. MSA fixed effects are included in all models. Standard errors are adjusted based on clustering at the MSA level.

Table 10: Shift of Asset Price Gradient and Muth-Mills Equation Variables 1985-1999					
Dep. Var.	Asset Price Ratio				
	(1)	(2)	(3)	(4)	(5)
time trend	-0.0007	-0.0024	-0.0002	0.0017	-0.0138
	[0.0031]	[0.0040]	[0.0124]	[0.0052]	[0.0191]
delay cost	0.1685***				0.1931***
	[0.0543]				[0.0646]
delay cost * time trend	-0.0022				-0.0039
	[0.0021]				[0.0027]
income		-0.0022			-0.0028
		[0.0068]			[0.0074]
income * time trend		0.0002			0.0005*
		[0.0002]			[0.0003]
dwelling age			-0.0187		-0.0048
			[0.0176]		[0.0163]
dwelling age^2			0.0004		0.0001
			[0.0003]		[0.0003]
dwelling age * time trend			0.0004		0.0008
			[0.0003]		[0.0011]
dwelling age^2 * time trend			-0.0000		-0.0000
			[0.0000]		[0.0000]
interior space				0.0043	0.0191
				[0.0154]	[0.0164]
interior space * time trend				-0.0008	-0.0036
				[0.0022]	[0.0026]
buildings with 10+ units				0.7827	0.4470
				[0.5021]	[0.4118]
buildings with 10+ units * time trend				0.0105	-0.0092
				[0.0174]	[0.0235]
constant	0.9790***	1.0541***	1.1772***	1.0112***	1.1011***
	[0.0177]	[0.1116]	[0.2559]	[0.0345]	[0.2796]
R2	0.46	0.47	0.45	0.45	0.48
N	440	536	607	607	440

Note: * p<0.1; ** p<0.05; *** p<0.01. This table reports the regression results of the ratio of rental price indices between the center city and the suburbs created based on the standard hedonic model. The main dependent variables are the time trend with 1985 = 0, 1987 = 2, ..., 2013 = 28. Delay cost is the annual total delay cost per commuter (1000$) as the sum of travel gas cost and congestion time cost, generated using the Urban Mobility Scoreboard constructed by Texas A&M Transportation Institute. Income is the per capita personal income (1000$) released by the Bureau of Economic Analysis (BEA). Dwelling age is the MSA weighted average dwelling age using the housing sampling weight from AHS. Interior space is the weighted average interior housing space (1000 sqft) based on the AHS sampling weights. Buildings with 10+ units is the percent of sampled housing units that are in buildings with 10+ units. MSA fixed effects are included in all models. Standard errors are adjusted based on clustering at the MSA level.

Table 11: Shift of Asset Price Gradient and Muth-Mills Equation Variables 1999-2013					
Dep. Var.	Asset Price Ratio				
	(1)	(2)	(3)	(4)	(5)
time trend	-0.0123*	-0.0053	-0.0170	0.0084	-0.0807**
	[0.0073]	[0.0097]	[0.0417]	[0.0330]	[0.0383]
delay cost	0.0199*				0.1555*
	[0.0105]				[0.0906]
delay cost * time trend	0.0105*				0.0098*
	[0.0061]				[0.0059]
income		-0.0098			0.0021
		[0.0082]			[0.0090]
income * time trend		0.0003			-0.0000
		[0.0003]			[0.0003]
dwelling age			0.0337		0.0872*
			[0.0458]		[0.0517]
dwelling age^2			-0.0004		0.0001
			[0.0006]		[0.0006]
dwelling age * time trend			-0.0003		0.0022
			[0.0019]		[0.0019]
dwelling age^2 * time trend			0.0000		-0.0000
			[0.0000]		[0.0000]
interior space				-0.1364	-0.1952
				[0.2957]	[0.2079]
interior space * time trend				-0.0019	0.0023
				[0.0150]	[0.0085]
buildings with 10+ units				-0.7273	-0.6009
				[0.6971]	[0.7467]
buildings with 10+ units * time trend				0.0046	0.0040
				[0.0288]	[0.0314]
constant	1.0688***	1.1861***	0.3632	1.1399*	1.6142
	[0.1048]	[0.2222]	[0.93199]	[0.6504]	[1.0992]
R2	0.38	0.27	0.32	0.32	0.40
N	440	535	608	608	440439

Note: * p<0.1; ** p<0.05; *** p<0.01. This table reports the regression results of the ratio of rental price indices between the center city and the suburbs created based on the standard hedonic model. The main dependent variables are the time trend with 1985 = 0, 1987 = 2, ..., 2013 = 28. Delay cost is the annual total delay cost per commuter (1000$) as the sum of travel gas cost and congestion time cost, generated using the Urban Mobility Scoreboard constructed by Texas A&M Transportation Institute. Income is the per capita personal income (1000$) released by the Bureau of Economic Analysis (BEA). Dwelling age is the MSA weighted average dwelling age using the housing sampling weight from AHS. Interior space is the weighted average interior housing space (1000 sqft) based on the AHS sampling weights. Buildings with 10+ units is the percent of sampled housing units that are in buildings with 10+ units. MSA fixed effects are included in all models. Standard errors are adjusted based on clustering at the MSA level.

Table 12: Shift of Rental Price Gradient and Muth-Mills Equation Variables 1985-1999					
Dep. Var.	Rental Price Ratio				
	(1)	(2)	(3)	(4)	(5)
time trend	0.0042	0.0157***	-0.0097	0.0075**	0.0029
	[0.0032]	[0.0050]	[0.0095]	[0.0038]	[0.0113]
delay cost	-0.0255				0.0099
	[0.0649]				[0.0663]
delay cost * time trend	-0.0028				-0.0009
	[0.0023]				[0.0023]
income		0.0111*			0.0119*
		[0.0067]			[0.0066]
income * time trend		-0.0002			0.0001
		[0.0003]			[0.0003]
dwelling age			-0.0028		-0.0088
			[0.0089]		[0.0090]
dwelling age^2			-0.0000		0.0001
			[0.0001]		[0.0001]
dwelling age * time trend			0.0008		0.0008
			[0.0005]		[0.0006]
dwelling age^2 * time trend			-0.0000		-0.0000
			[0.0000]		[0.0000]
interior space				-0.0207*	-0.0158*
				[0.0122]	[0.0096]
interior space * time trend				0.0003	-0.0013
				[0.0024]	[0.0015]
buildings with 10+ units				0.0550	-0.0681
				[0.1178]	[0.0979]
buildings with 10+ units * time trend				-0.0149	-0.0057
				[0.0111]	[0.0116]
constant	1.0080***	1.1220***	1.2166***	0.9734***	1.4700***
	[0.0156]	[0.1093]	[0.1847]	[0.0319]	[0.2179]
R2	0.52	0.54	0.63	0.63	0.55
N	440	536	607	607	440

Note: * $p<0.1$; ** $p<0.05$; *** $p<0.01$. This table reports the regression results of the ratio of rental price indices between the center city and the suburbs created based on the standard hedonic model. Time trend is coded with 1985 = 0, 1987 = 2, ..., 2013 = 28. Delay cost is the annual total delay cost per commuter (1000$) as the sum of travel gas cost and congestion time cost, generated using the Urban Mobility Scoreboard constructed by Texas A&M Transportation Institute. Income is the per capita personal income (1000$) released by the Bureau of Economic Analysis (BEA). Dwelling age is the MSA weighted average dwelling age using the housing sampling weight from AHS. Interior space is the weighted average interior housing space (1000 sqft) based on the AHS sampling weights. Buildings with 10+ units is the percent of sampled housing units that are in buildings with 10+ units. MSA fixed effects are included in all models. Standard errors are adjusted based on clustering at the MSA level.

Table 13: Shift of Rental Price Gradient and Muth-Mills Equation Variables 1999-2013					
Dep. Var.	Rental Price Ratio				
	(1)	(2)	(3)	(4)	(5)
time trend	-0.0027	-0.0004	-0.0200	0.0046	-0.0241
	[0.0041]	[0.0058]	[0.0325]	[0.0096]	[0.0285]
delay cost	-0.2279***				-0.1975*
	[0.0782]				[0.0145]
delay cost * time trend	0.0028				0.0027
	[0.0032]				[0.0041]
income		0.0049			0.0078
		[0.0091]			[0.0091]
income * time trend		-0.0001			-0.0002
		[0.0002]			[0.0002]
dwelling age			-0.0446*		-0.0134
			[0.0262]		[0.0198]
dwelling age^2			0.0005*		0.0001
			[0.0003]		[0.0002]
dwelling age * time trend			0.0011		0.0008
			[0.0013]		[0.0011]
dwelling age^2 * time trend			-0.0000		-0.0000
			[0.0000]		[0.0000]
interior space				-0.2094*	-0.2624*
				[0.1238]	[0.1414]
interior space * time trend				-0.0095	-0.0000
				[0.0069]	[0.0006]
buildings with 10+ units				-0.3031	-0.2268
				[0.3050]	[0.3272]
buildings with 10+ units * time trend				0.0209*	0.0049
				[0.0129]	[0.0144]
constant	1.2365***	0.9716***	1.8519***	0.9490***	1.4699***
	[0.0757]	[0.2432]	[0.5366]	[0.1892]	[0.0.5012]
R2	0.51	0.48	0.51	0.51	0.53
N	440	535	608	608	439

Note: * p<0.1; ** p<0.05; *** p<0.01. This table reports the regression results of the ratio of rental price indices between the center city and the suburbs created based on the standard hedonic model. Time trend is coded with 1985 = 0, 1987 = 2, ..., 2013 = 28. Delay cost is the annual total delay cost per commuter (1000$) as the sum of travel gas cost and congestion time cost, generated using the Urban Mobility Scoreboard constructed by Texas A&M Transportation Institute. Income is the per capita personal income (1000$) released by the Bureau of Economic Analysis (BEA). Dwelling age is the MSA weighted average dwelling age using the housing sampling weight from AHS. Interior space is the weighted average interior housing space (1000 sqft) based on the AHS sampling weights. Buildings with 10+ units is the percent of sampled housing units that are in buildings with 10+ units. MSA fixed effects are included in all models. Standard errors are adjusted based on clustering at the MSA level.

Figure 1: Annual Average Appreciation Rates of National House Price Indices

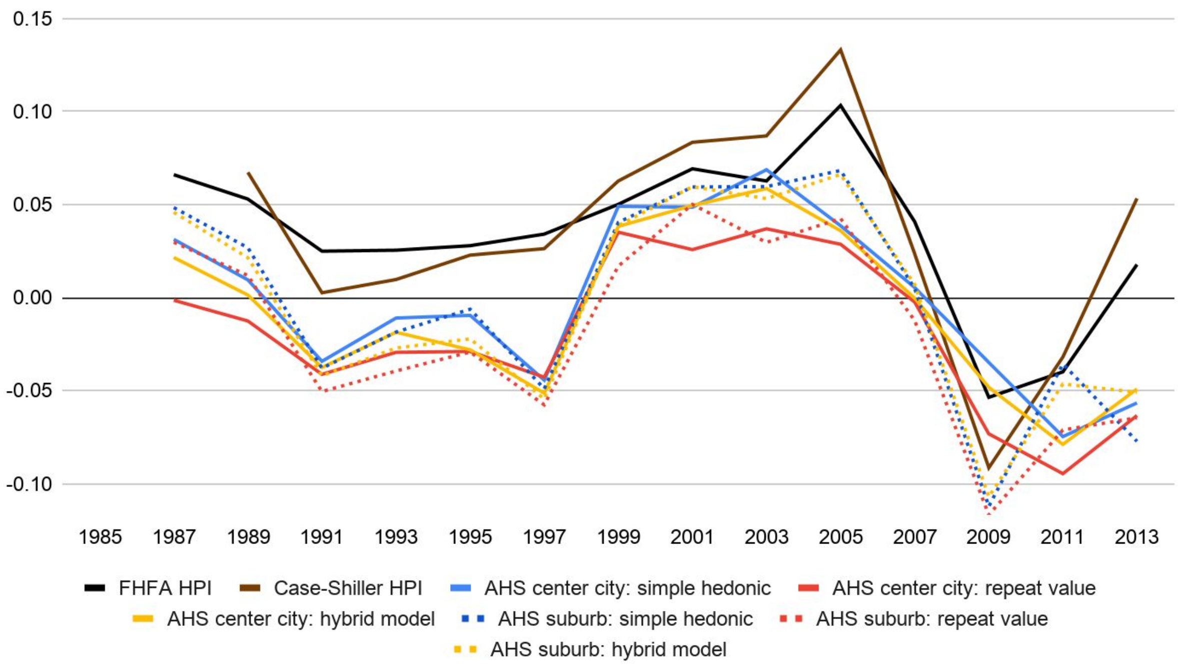


Figure 2. Annual Average Appreciation Rates of Rental Price Indices Using AHS Data

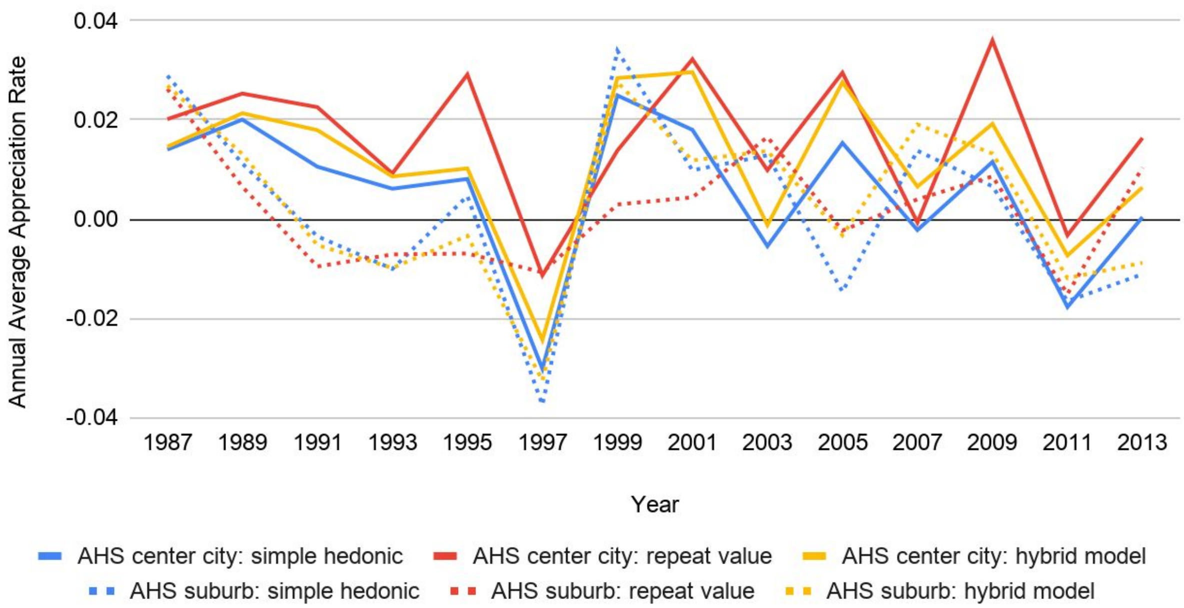


Figure 3: Fractions of MSAs by asset price gradient shift and housing market size

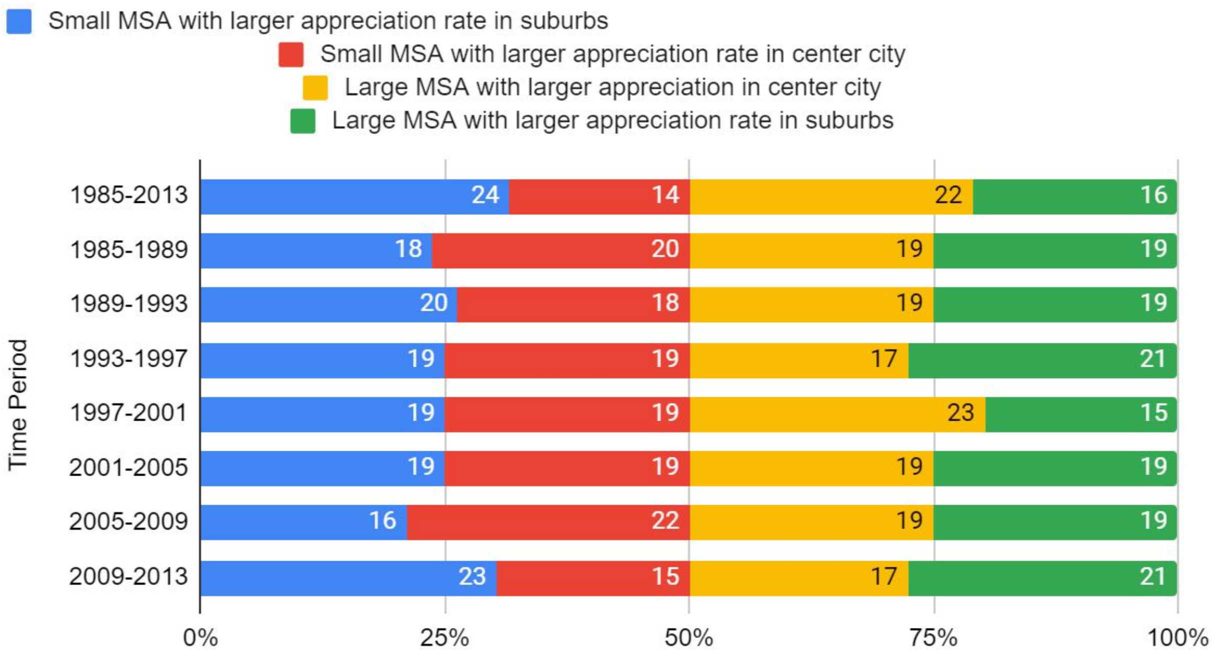
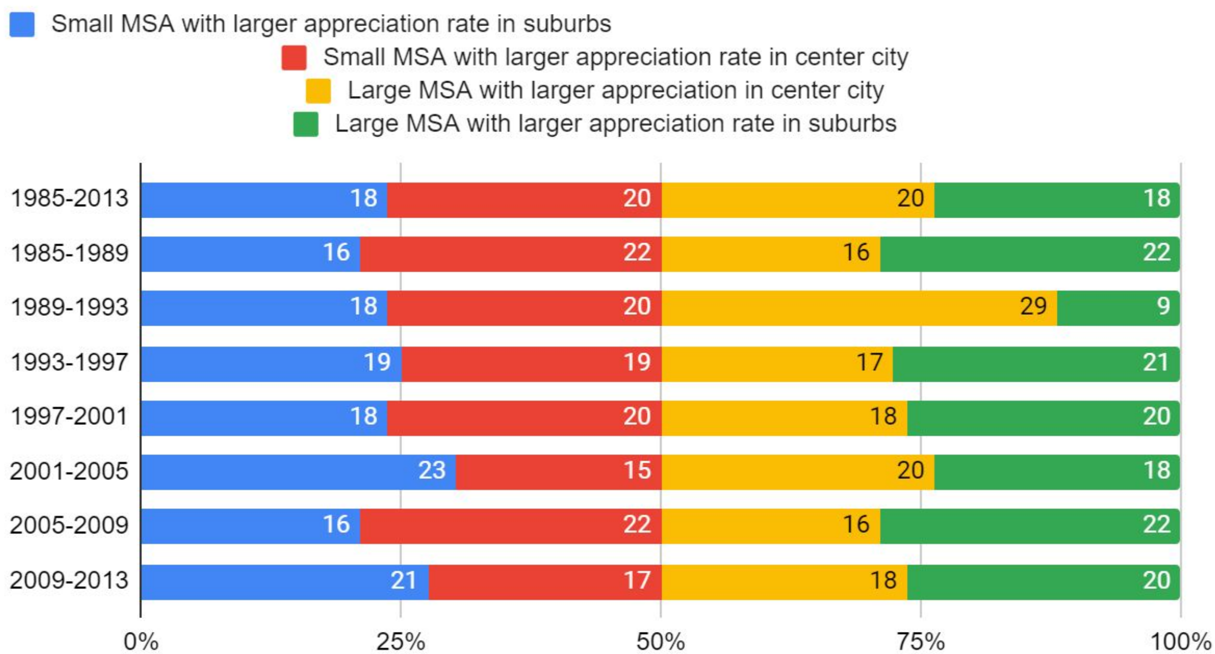


Figure 4. Fraction of MSAs by rental price gradient shift and housing market size



Appendix

A1. Number of Housing Units Sampled by MSA, by Metro Status, and by Model (Owner-occupied Market)

MSA Name	Number of Housing Units					
	Model A: standard hedonic		Model B: repeat-value		Model C: Hybrid	
	Center City	Suburb	Center City	Suburb	Center City	Suburb
Albany-Schenectady-Troy, NY	283	502	117	261	278	499
Allentown-Bethlehem-Easton, PA	290	309	122	145	286	307
Atlanta, GA	672	2,203	172	916	555	2,164
Bakersfield, CA	299	187	164	85	294	184
Baltimore, MD	1,029	1,627	354	745	1,014	1,618
Baton Rouge, LA	289	299	108	154	283	288
Bergen-Passaic, NJ	80	1,738	18	735	76	1,721
Birmingham, AL	731	653	146	324	390	645
Boston, MA	887	2,644	332	1,174	871	2,615
Bridgeport-Milford, CT	399	474	160	228	395	468
Canton, OH	213	230	101	129	201	230
Chattanooga, TN-GA	244	258	105	131	234	256
Chicago, IL	3,820	6,396	1,237	3,028	3,591	6,320
Cincinnati, OH-KY-IN	527	1,257	147	617	380	1,242
Cleveland, OH	863	2,061	271	1,080	649	2,040
Columbia, SC	121	412	52	224	119	402
Columbus, OH	1,580	568	417	297	873	566
Dallas, TX	3,602	1,955	1,370	966	2,634	1,691
Denver, CO	1,496	282	462	127	1,080	278
Detroit, MI	2,013	9,748	724	3,992	1,825	8,722
Flint, MI	203	245	106	139	200	241
Fort Lauderdale-Hollywood, FL	651	1,693	228	714	637	1,674
Fresno, CA	394	199	207	112	390	197
Gary-Hammond, IN	290	419	151	187	283	416
Grand Rapids, MI	371	505	183	273	363	495
Greenville-Spartanburg, SC	156	470	66	225	154	470
Honolulu, HI	435	386	152	173	427	380
Houston, TX	2,047	1,477	981	797	2,010	1,451

Indianapolis, IN	1,839	323	481	176	982	321
Jersey City, NJ	162	284	50	80	154	275
Johnson City-Kingsport-Bristol, TN-VA	177	274	64	120	175	272
Joliet-Naperville, IN-WI	137	365	61	183	135	362
Kansas City, MO-KS	1,338	1,002	446	544	951	998
Knoxville, TN	279	273	129	131	267	272
Lake County, IL	219	840	78	403	209	835
Las Vegas, NV	562	626	249	324	559	621
Lawrence-Haverhill, MA-NH	148	143	63	57	145	143
Los Angeles-Long Beach, CA	5,694	8,622	1,969	3,779	5,127	8,299
Memphis, TN-AR-MS	1,516	341	459	187	899	340
Miami-Hialeah, FL	713	2,036	231	802	685	1,995
Milwaukee, WI	1,323	982	479	563	879	976
Minneapolis-Saint Paul, MN	1,112	2,387	527	1,151	1,103	2,366
New Haven-Meriden, CT	147	374	65	156	145	372
New Orleans, LA	1,266	741	283	366	694	723
New York City, NY	6,233	3,670	1,784	1,548	5,940	3,631
Norfolk-Portsmouth, VA	1,831	1,070	842	167	1,597	331
Oklahoma City, OK	837	395	438	227	821	390
Omaha, NE-IA	536	256	256	118	534	254
Orlando, FL	187	1,157	80	579	183	1,140
Oxnard-Ventura, CA	273	497	133	269	260	493
Peoria, IL	243	166	122	67	242	164
Philadelphia, PA-NJ	2,940	8,176	1,129	3,193	2,688	7,418
Phoenix, AZ	3,159	1,091	1,249	451	2,810	879
Pittsburgh, PA	680	2,304	228	1,117	551	2,283
Providence, RI	442	707	49	349	131	703
Riverside-San Bernardino, CA	695	2,040	272	1,049	577	1,911
Rochester, NY	250	805	125	443	242	801
Sacramento, CA	1,010	839	363	468	666	836
Saint Louis, MO-IL	673	1,995	266	1,042	541	1,972
Salt Lake City-Ogden, UT	414	1,187	166	522	404	1,177
San Antonio, TX	1,277	225	675	128	1,256	214
San Diego, CA	2,259	1,262	748	609	1,548	1,252
San Francisco, CA	2,324	3,477	595	1,656	1,528	3,444

San Jose, CA	2,014	916	553	452	1,051	907
Scranton-Wilkes Barre, PA	235	472	98	241	230	468
Seattle, WA	991	1,642	389	742	979	1,621
Springfield, MA	287	347	149	174	283	347
Syracuse, NY	191	315	91	158	188	312
Tacoma, WA	279	320	117	180	274	315
Tampa-Saint Petersburg-Clearwater, FL	1,051	2,090	463	961	1,032	2,072
Toledo, OH	543	248	292	143	538	247
Tucson, AZ	647	392	267	171	635	389
Washington, DC-MD-VA	945	3,646	345	1,557	913	3,602
West Palm Beach-Boca Raton, FL	435	1,132	173	446	420	1,122
Worcester, MA	272	122	132	66	271	118
Youngstown-Warren, OH	193	392	90	197	192	380
Total	74,963	102,163	26,966	46,490	63,126	97,943

Source: U.S. Department of Housing and Urban Development and U.S. Census Bureau, American Housing Survey 1985-2013

Note: Econometric details of Model A-C are explained in Equation (1)-(7).

A2. Number of Housing Units Sampled by MSA, by Metro Status, and by Model (Rental Market)						
MSA Name	Number of Housing Units					
	Model A: standard hedonic		Model B: repeat-value		Model C: Hybrid	
	center city	suburb	center city	suburb	center city	suburb
Albany-Schenectady-Troy, NY	374	218	145	91	368	214
Allentown-Bethlehem-Easton, PA	295	184	118	73	293	180
Atlanta, GA	843	1,556	208	451	723	1,505
Bakersfield, CA	191	122	59	39	187	118
Baltimore, MD	870	896	282	379	848	882
Baton Rouge, LA	253	108	75	30	249	105
Bergen-Passaic, NJ	180	866	78	310	177	848
Birmingham, AL	582	234	104	86	282	226
Boston, MA	1,233	1,484	445	535	1,216	1,457
Bridgeport-Milford, CT	383	68	116	38	374	62
Canton, OH	161	53	60	16	160	53
Chattanooga, TN-GA	216	98	72	43	215	95
Chicago, IL	4,445	2,270	1,156	761	4,264	2,179
Cincinnati, OH-KY-IN	691	585	202	280	523	570
Cleveland, OH	726	768	186	277	486	748
Columbia, SC	87	211	34	74	84	205
Columbus, OH	1,717	215	408	88	1,080	209
Dallas, TX	4,038	1,369	1,026	396	2,986	1,090
Denver, CO	1,406	53				
Detroit, MI	1,199	2,889	346	837	1,068	2,417
Flint, MI	99	137	39	60	97	127
Fort Lauderdale-Hollywood, FL	478	780	183	276	456	749
Fresno, CA	423	146	122	47	406	139
Gary-Hammond, IN	238	125	77	44	233	123
Grand Rapids, MI	183	196	71	74	179	191
Greenville-Spartanburg, SC	83	112			81	105
Honolulu, HI	411	249	110	88	404	248
Houston, TX	2,445	784	634	252	2,379	754
Indianapolis, IN	1,713	161	365	57	963	161

Jersey City, NJ	625	385	281	154	621	382
Johnson City-Kingsport-Bristol, TN-VA	68	39	24	12	66	33
Joliet-Naperville, IN-WI	90	66	29	19	89	63
Kansas City, MO-KS	1,093	500	276	204	775	494
Knoxville, TN	282	160	85	53	278	158
Lake County, IL	150	161	28	59	140	156
Las Vegas, NV	392	569	115	185	379	561
Lawrence-Haverhill, MA-NH	106	110	37	56	106	110
Los Angeles-Long Beach, CA	8,690	6,968	2,292	2,316	7,994	6,517
Memphis, TN-AR-MS	1,221	202	243	49	642	199
Miami-Hialeah, FL	893	1,061	270	315	868	1,013
Milwaukee, WI	1,230	373	247	159	714	366
Minneapolis-Saint Paul, MN	862	881	345	264	839	864
New Haven-Meriden, CT	299	109	126	44	299	103
New Orleans, LA	1,093	455	162	143	619	446
New York City, NY	12,839	1,994	4,306	649	12,638	1,944
Norfolk-Portsmouth, VA	1,495	555	516	34	1,244	93
Oklahoma City, OK	769	249	322	96	752	239
Omaha, NE-IA	452	101	138	25	449	99
Orlando, FL	306	607	113	216	304	580
Oxnard-Ventura, CA	225	242	98	98	222	232
Peoria, IL	156	58	65	19	155	55
Philadelphia, PA-NJ	1,961	2,448	590	661	1,754	2,163
Phoenix, AZ	2,215	496	467	100	1,755	270
Pittsburgh, PA	578	745	158	286	450	723
Providence, RI	553	353	103	142	282	348
Riverside-San Bernardino, CA	638	985	172	301	488	807
Rochester, NY	386	227	142	91	384	225
Sacramento, CA	1,072	706	271	247	741	697
Saint Louis, MO-IL	639	763	187	339	496	740
Salt Lake City-Ogden, UT	312	433	123	187	299	415
San Antonio, TX	1,127	91	412	26	1,110	84
San Diego, CA	2,413	1,164	601	383	1,643	1,142
San Francisco, CA	3,311	2,117	707	772	2,121	2,075
San Jose, CA	1,328	603	215	217	669	590

Scranton-Wilkes Barre, PA	171	210	66	102	165	205
Seattle, WA	973	931	359	341	955	897
Springfield, MA	324	199	136	87	321	197
Syracuse, NY	226	138	63	45	220	137
Tacoma, WA	282	352	117	162	276	348
Tampa-Saint Petersburg-Clearwater, FL	732	816	228	263	710	768
Toledo, OH	315	88	99	29	304	87
Tucson, AZ	538	144	162	25	518	139
Washington, DC-MD-VA	1,225	1,742	360	581	1,200	1,671
West Palm Beach-Boca Raton, FL	232	392	68	120	224	372
Worcester, MA	181	57	67	27	176	57
Youngstown-Warren, OH	117	150	40	45	112	143
Total	81,148	49,132	22,752	16,450	68,347	45,767

Source: U.S. Department of Housing and Urban Development and U.S. Census Bureau, American Housing Survey 1985-2013

Note: Econometric details of Model A-C are explained in Equation (1)-(7).

Table A3: Summary Statistics of Annual Average Real Appreciation Rates in Owner-occupied Market							
Year	Num. of Obs.	Standard Hedonic Model		Repeat-value Model		Hybrid Model	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Panel A: Center City							
1987	76	4.52%	0.097	8.61%	0.386	3.62%	0.118
1989	76	1.32%	0.086	2.63%	0.284	1.45%	0.102
1991	76	-2.86%	0.080	-1.68%	0.218	-4.23%	0.104
1993	76	-0.48%	0.075	-0.03%	0.213	1.39%	0.235
1995	76	-1.86%	0.073	0.86%	0.254	-2.27%	0.096
1997	76	-1.64%	0.132	4.90%	0.310	-1.45%	0.162
1999	76	6.20%	0.265	617.85%	53.649	4.99%	0.298
2001	76	6.96%	0.218	5.05%	0.267	6.30%	0.226
2003	76	3.04%	0.150	7.31%	0.335	3.04%	0.159
2005	76	6.59%	0.193	7.07%	0.292	5.06%	0.219
2007	76	1.89%	0.215	11.33%	0.442	3.05%	0.235
2009	76	-1.41%	0.212	-4.54%	0.412	-2.49%	0.246
2011	76	-7.15%	0.147	-7.97%	0.209	-7.79%	0.166
2013	76	1.37%	0.387	9.96%	1.229	2.58%	0.447
Panel B: Suburb							
1987	76	4.09%	0.081	2.63%	0.125	4.11%	0.089
1989	76	1.46%	0.066	-0.45%	0.104	1.79%	0.078
1991	76	-1.90%	0.066	-3.53%	0.086	-1.27%	0.079
1993	76	-1.63%	0.048	-3.75%	0.079	-1.95%	0.064
1995	76	-0.94%	0.054	-2.26%	0.091	-0.28%	0.080
1997	76	-2.20%	0.093	-3.66%	0.101	-2.04%	0.090
1999	76	2.33%	0.102	-0.59%	0.253	2.82%	0.106
2001	76	6.73%	0.150	6.88%	0.348	8.59%	0.194
2003	76	4.64%	0.141	2.01%	0.111	4.67%	0.127
2005	76	6.39%	0.154	4.58%	0.127	6.89%	0.155
2007	76	2.78%	0.171	-0.06%	0.161	2.38%	0.134
2009	76	-7.99%	0.152	-10.50%	0.171	-8.31%	0.159
2011	76	-2.04%	0.210	-6.06%	0.195	-1.19%	0.270
2013	76	-5.44%	0.181	8.29%	1.021	-4.19%	0.188

Table A4: Summary Statistics of Annual Average Real Appreciation Rates in Rental Markets							
Year	Num. of Obs.	Standard Hedonic Model		Repeat-value Model		Hybrid Model	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Panel A: Center City							
1987	76	3.22%	0.092	6.75%	0.421	2.65%	0.093
1989	76	0.37%	0.077	1.83%	0.154	0.34%	0.104
1991	76	1.42%	0.088	4.77%	0.203	0.52%	0.084
1993	76	-0.43%	0.078	0.36%	0.117	1.07%	0.089
1995	76	0.53%	0.068	1.03%	0.136	-0.48%	0.072
1997	76	-1.70%	0.095	1.01%	0.148	-0.45%	0.109
1999	76	1.74%	0.114	-1.99%	0.158	1.19%	0.119
2001	76	2.29%	0.093	0.68%	0.124	1.51%	0.087
2003	76	1.94%	0.115	8.08%	0.498	1.86%	0.111
2005	76	1.30%	0.088	0.87%	0.150	1.18%	0.086
2007	76	0.70%	0.097	1.64%	0.136	1.20%	0.109
2009	76	-0.67%	0.125	2.18%	0.229	-0.35%	0.128
2011	76	2.25%	0.178	3.83%	0.184	0.47%	0.100
2013	76	-1.01%	0.118	32.05%	2.607	-0.57%	0.218
Panel B: Suburb							
1987	76	2.04%	0.115	7.22%	0.387	2.77%	0.143
1989	76	3.91%	0.097	3.80%	0.265	4.16%	0.129
1991	76	1.47%	0.075	3.87%	0.245	2.88%	0.127
1993	76	0.83%	0.072	3.06%	0.297	1.14%	0.120
1995	76	0.69%	0.092	7.13%	0.312	2.68%	0.186
1997	76	-3.16%	0.092	0.54%	0.220	-1.48%	0.126
1999	76	2.42%	0.121	2.30%	0.255	3.72%	0.164
2001	76	3.02%	0.117	5.79%	0.278	4.55%	0.162
2003	76	-0.23%	0.131	1.92%	0.270	1.24%	0.158
2005	76	2.22%	0.152	5.16%	0.236	4.18%	0.148
2007	76	0.39%	0.146	223.20%	42.700	0.87%	0.170
2009	76	3.88%	0.389	402.96%	34.089	4.61%	0.384
2011	76	0.70%	0.123	9.32%	0.395	1.00%	0.178
2013	76	-0.29%	0.156	1.12%	0.246	-0.59%	0.163