A Constant Quartile Mismatch Indicator of Changing Rental Affordability in U.S. Metropolitan Areas, 2000 to 2016

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Abstract

This article proposes a new measure of rental affordability to estimate the growing mismatch between changes in rent and income. Quartiles defined in 2000 for each area are updated for inflation and then used to describe rent and income distributions in 2016, comparing the 50 largest metropolitan areas with census and American Community Survey (ACS) data. The features and advantages of this constant quartile mismatch (CQM) indicator are compared with alternative indicators of affordability, including excessive rent burden and low-income housing supply gap. Unlike the other indicators, rent and income changes are separately identified, which explains the curious anomaly that the San Francisco or Washington, D.C., areas have been measured more affordable than the national average. The mismatch indicator in contrast measures growing stress on renters at both the high and low ends of the distribution. Strong upward shifts in rents are unmatched by increases in incomes in the top quartile, whereas losses of rentals in the bottom quartile leave low-income renters with much less opportunity than they had before. The new method thus conveys how the affordability problems in the lower end of the housing market are linked to shifts in the upper quartile and directly to losses in the bottom quartile. This broader characterization of affordability could help build broader based support for solving housing problems.

List of Exhibits

Introduction

The housing affordability crisis in the United States has drawn widespread attention for its severity since the onset of the Great Recession. Although the affordability problem has been mounting since the 1970s, in recent years it reached its greatest intensity, only slightly moderated since 2011. More than 38 million U.S. households, including homeowners and renters, paid more than 30 percent of their income for housing in 2016 (JCHS, 2018). This means that nearly one-third of all U.S. households live in housing they cannot afford. The affordability problem is especially severe among renters. The Census Bureau's 2016 American Community Survey (Ruggles et al., 2018) finds that nearly one-half (47.5 percent) of all renters were cost burdened, paying 30 percent or more of their income on rent.

Lack of housing affordability has serious consequences for households and their communities, placing greater stress on family budgets and leading to reduced retail spending in the community (Gabriel and Painter, 2018). This is a problem that many urban residents complain about, including renters and homeowners. A recent study based on Fannie Mae's National Housing Survey[1] shows that about one-half of housing consumers, both homeowners and renters, say that housing in their area has become less affordable—renters more so than homeowners (Fannie Mae, 2018). Among renters with incomes above the median for their area, 61 percent feel that housing has become less affordable in their area in the last few years, compared to 50 percent of renters with lower income (Fannie Mae, 2018: 17). In fact, the Joint Center for Housing Studies (JCHS) of Harvard University shows how the percent of renters paying more than 30 percent of income for rent is greatest for lower income groups, but that incidence of excessive rent burden has been steadily climbing upward in moderate- and middle-income groups (see figure 28 in JCHS, 2017).

The traditional means of measuring housing affordability is the ratio of housing expenses to household income, as used in relation to the 30-percent criterion threshold for defining excess cost burden.[2] This concept of individual-based housing affordability is generalized to entire market areas by averaging the ratios of local residents; however, that indicator is not wholly adequate for a number of reasons to be discussed. As a result, at least three alternative indicators have been proposed previously, each of which has value for illuminating a different facet of the housing affordability problem. Those include indicators of low-income *supply gap*, actual *availability* of low-cost housing for low-income tenants (after subtracting moderate- and higher income occupants), and the *shelter poverty* measurement (computing housing cost burdens relative to residual income after budget allocations for food and other necessities).

The authors propose an additional indicator for evaluating housing affordability that meets measurement needs not addressed by the others. The *constant quartile mismatch* indicator compares changes in the rent and income distributions since a baseline year to describe growing affordability problems in both high- and low-price brackets. The features of this mismatch indicator are compared with the other affordability indicators and its advantages discussed. It does not replace

1 Fannie Mae launched the National Housing Survey (NHS) in 2010 to generate new information about consumer attitudes, intentions, and financial conditions that pertain to housing and mortgage markets (Fannie Mae, 2018). The NHS is the only large, national, monthly survey of consumers focused primarily on housing. The responses of the nationally representative sample of 1,000 consumers to about 100 questions provide information on a wide range of housing-related topics.

2 Small technical differences exist in how the 30-percent threshold is applied. Although the HUD definition of *excess cost burden* is "greater than" 30 percent of income spent on housing, the published data by the Census Bureau reports data that are "at or above" 30 percent. Analysis based on the "greater than" standard yields a slightly *lower* incidence of rent burden than that derived from the published Census data. A second difference concerns how to handle the category of renters for which complete data are not available. The most common approach ignores households with missing data and calculates the share of renters paying excessive rent among cases with complete data only. By contrast, the Harvard JCHS allocates the cases with missing data into two different rent burden groups. Units paying no cash rent (roughly one-third of the "not computed" subgroup) are assigned to the no-burden group, whereas zero-or-negative-income units (roughly two-thirds of the "not computed" subgroup) are assigned to the 50-percent+ burden group. This inclusive approach has the advantage of using available data to count all renters in the nation. That has the effect of slightly *raising* the incidence of rent burden compared with when the not-computed cases are excluded. Throughout this article, we follow the Harvard JCHS's approach to using the "not computed" subgroup and also the "greater than" treatment of the 30-percent and 50-percent thresholds, both of which differ from common analysis with the Census Bureau data.

any of the other indicators, but it may work particularly well in combination with the traditional rent burden indicator, whose faults it at least partly redresses.

In brief, the proposed mismatch indicator separately tracks trends in renters' incomes and rents paid, calling attention to which quartiles of the rent distribution have greater changes than the corresponding changes in income quartiles, using a constant, inflation-adjusted set of quartiles established for the base year, which is 2000 for this analysis. Those shifts are grounded in each metropolitan area's distribution of rents and incomes, corresponding to local residents' market experiences and distinguishing affordability problems caused by falling incomes from those caused by rising rents. The results from the proposed method are easily graphed and are intuitively understandable to local residents, so the results of the new indicator may help to support better public understanding of the magnitude of the affordability problem in different localities.

This article begins with a brief review of the literature on alternative measures of access to affordable housing. We start with a review of the current findings from the traditional rent burden indicator of affordability, which is by far the one most commonly used because of its simplicity but which has a number of deficiencies or limitations. Every indicator has strengths and limitations, and we compare the alternatives on several features.

The constant quartile mismatch indicator is compared with the alternatives and its method is explained, both quantitatively and graphically. We summarize results of this mismatch indicator for the nation and the 50 largest metropolitan areas, examining several more closely. Following that, we discuss how a metropolitan planning organization (MPO) might choose to use this rental affordability indicator and what added practical value it might bring to local deliberations.

The Traditional Rent Burden Indicator

The most intuitive concept about housing affordability is that renters cannot afford to pay more than a certain share of their income for housing. Once, a rule of thumb of 25 percent was commonly used, based on a 19th-century practice in factory housing of charging a week's pay for a month's rent (Feins and Saunders Lane, 1981). Since 1981, standard practice of the Federal, state, and local governments is to judge housing affordable if the household pays no more than 30 percent of its income for gross housing expenses (including rent, utilities, and applicable taxes) (HUD, 2014). Households paying more than 30 percent are judged to have an excessive rent burden, whereas households paying more than 50 percent have severe rent burden.

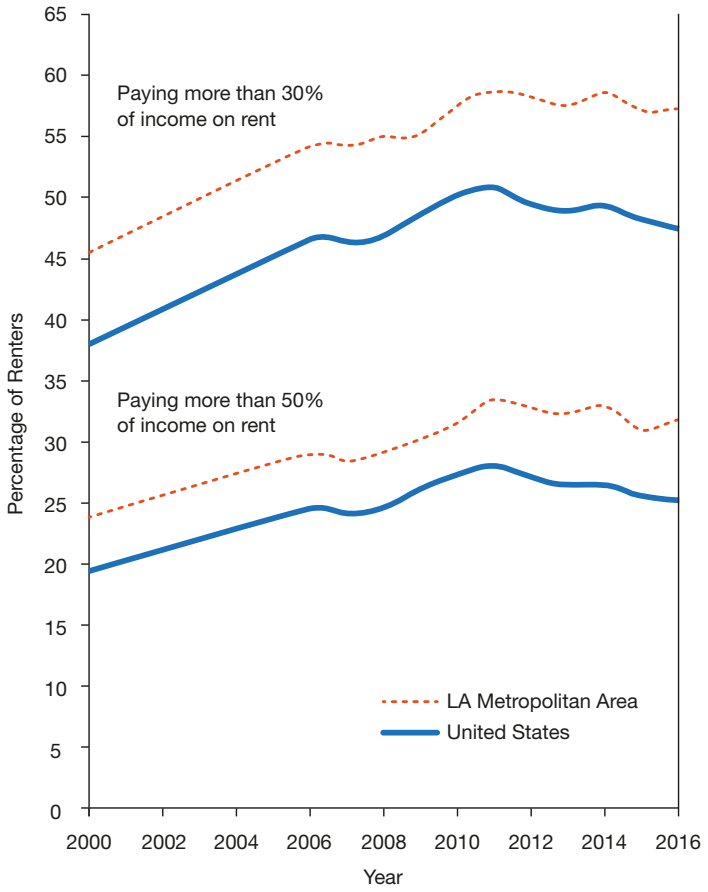
Aggregated across all rental households in an area, this traditional measure of housing affordability is the one most commonly used to describe the affordability of cities and metropolitan areas. Most of what is known about the depth of the problem and its extent across the country is based on the traditional indicator of rent burden (Collinson, 2011; HUD, 2017a; JCHS, 2018; Quigley and Raphael, 2004). In fact, virtually every study of housing affordability uses the traditional rent burden indicator for at least part of its analysis.

The Trend Over Time

The rent burden indicator of affordability problems for a jurisdiction is the share of local renters that pay more than 30 percent of income on housing expenses. As shown for the nation in exhibit 1, that indicator describes growing affordability problems since 2000, which rose to a plateau immediately after the Great Recession and moderated slightly thereafter.[3] Also shown is

Exhibit 1

Trend of Rent Burden, 2000 to 2016, United States and Los Angeles Metropolitan Area



Sources: 2000 Decennial Census; Census Bureau, 2006 to 2016 American Community Survey, *Integrated Public Use Microdata (IPUMS) Series, Microdata files (Ruggles et al., 2018).*

3 The total incidence of rent burden (more than 30 percent of income) in the nation was 47.5 percent in 2016 compared with 38.0 percent in 2000, an increase of 9.5 percentage points. The incidence of rent burden peaked in the nation at 50.7 percent in 2011 but sustained an even higher plateau of about 58.5 percent through 2014 in the Los Angeles metropolitan area. Colburn and Allen (2018) found a similar national trend in rent burden before and after the Great Recession using the U.S. Census Bureau's Survey of Income and Program Participation data. The prevalence of rent burden in their study had already peaked in 2009 (2 years earlier than in the ACS-based trend) and moderated slightly by 2011, but it remained at elevated levels relative to the prerecession period.

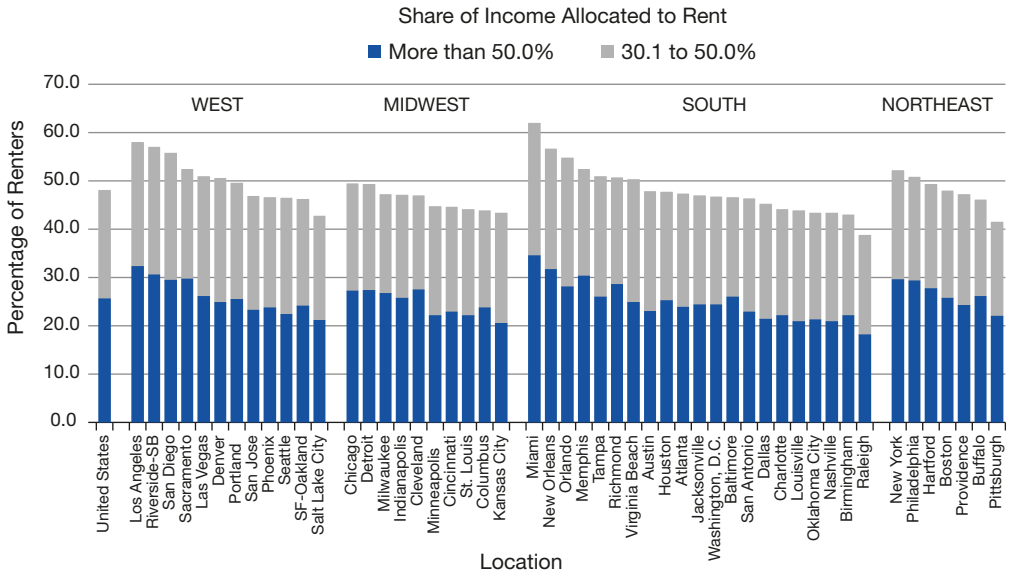
the indicator value for the Los Angeles metropolitan area,[4] which frequently is cited as one of the highest in the nation (JCHS, 2018; NLIHC, 2018a; NYU Furman Center, 2017; Urban Institute, 2017). Increases in Los Angeles track closely with the national trend. The share of renters with severe affordability problems is nearly one-half of all cost-burdened renters in both the nation and Los Angeles, and it rises in parallel with overall affordability problems.[5]

Comparing Metros on Incidence of Rent Burden

Viewed across metropolitan areas, the rent burden indicator is surprisingly invariant, with fairly similar problem incidence in the great majority of metropolitan areas (exhibit 2). In all but 5 metropolitan areas, the incidence of excessive rent burden deviates no more than 8 percentage points from the national average. Also, the share of total excess rent burden that is severe (more

Exhibit 2

Share of Renter Households Who Are Cost Burdened, United States and Largest 50 Metropolitan Areas, 2016



Source: 2016 American Community Survey IPUMS Microdata files (Ruggles et al., 2018).

4 We adopt the Los Angeles metropolitan area as a frequent illustration in this study because of its exceptionally large affordability problems. The research used in this study is from a project supported by the Los Angeles-based Haynes Foundation. We compared data for other large metropolitan areas to make better sense of the data for Los Angeles.

5 Similarly, the incidence of severe rent burden is proportionally higher in the nation in 2016 than it was in 2000, 25.2 percent compared with 19.6 percent, an increase of 5.6 percentage points. Overall, the incidence of severe rent burden is almost exactly one-half of total rent burden, 51.6 percent and 53.0 percent in 2000 and 2016, respectively, as is the change in severe burden compared with the change in total burden. Incidence of severe rent burden (more than 50 percent of income) also peaked in the nation and Los Angeles in 2011 and then began to taper downward. Severe rent burden is a subset of total rent burden, and in 2016 that remained a problem in the United States for 25.2 percent of renters, almost exactly one-half of the 53.0 percent of renters who were paying more than 30 percent of income for rent. In the Los Angeles metropolitan area, the incidence of extreme rent burden was slightly greater than one-half of total renter burden, 31.8 compared with 57.3 percent.

than 50 percent of income) is remarkably similar—roughly one-half—in every metropolitan area in 2016 (as it was in 2000, not shown). One might assume that the nation's housing affordability problems would be more extremely measured in certain metropolitan areas than they seem to be on this indicator.

Not only is there great similarity across metropolitan areas, but some very high-cost areas have unusually low affordability problems, according to this indicator. A major puzzle is how the rent burden indicator in the San Francisco-Oakland metro, as well as San Jose and Seattle metropolitan areas, could be actually lower, more favorable, than the national average and even lower than many of the larger Midwestern, Northeastern, or Southern metropolitan areas. That defies the public image that the San Francisco area is among the least affordable in the nation. The explanation for this anomaly, as also noted in previous studies (JCHS, 2018; NLIHC, 2018a; NYU Furman Center, 2017; Urban Institute, 2017), is very likely that higher incomes prevailing in the growing high-tech metropolitan areas helped to offset their higher rents.[6]

This finding of surprisingly "affordable" tech metropolitan areas illustrates the general limitation of the rent burden indicator: that it does not distinguish between rent and income effects. We cannot tell if housing is made unaffordable by rising rents or falling incomes; hence, based on this indicator, we cannot identify what is the problem or the solution. The further drawback, as discussed, is that the rent burden indicator reveals so little variation across locations, which makes it less appropriate to use for prioritizing areas with higher or lower affordability problems.

Finally, this indicator is an average across renters of all income levels that, although useful as a summary, could well disguise unique variations in the problems facing each metropolitan area. Other indicators, discussed next, are designed to shed light on the affordability problem in different ways.

Alternative Measures of Rental Affordability

Rental affordability problems can be measured in different ways, and those ways are reviewed here briefly as necessary background for appreciating the contribution of the proposed new indicator. Housing problems are greatest for households with the lowest incomes, but those problems include more than just costs. A significant biannual report to Congress by HUD (2017b) summarizes "worst case" housing needs as afflicting 8.2 million very low-income renters (earning at or below 50 percent of area median income, hereafter AMI) in 2015. Those households are defined as very low-income renters who do not receive government housing assistance and who pay more than one-half of their income for rent, live in severely inadequate conditions, or both (HUD, 2017b). High rents in proportion to renter incomes remain a prominent factor among households with worst case needs, leaving those renters with a substantial, unmet need for affordable housing.

6 Median rent in 2016, as reported by the ACS, was $1,750 in San Francisco-Oakland and $2,076 in San Jose, compared with only $1,410 in the Los Angeles metropolitan area. Even though median rent had increased more rapidly in Los Angeles since 2000 (36.7 percent) than in the Bay Area (35.0 percent and 27.6 percent in San Francisco-Oakland and San Jose, respectively), Los Angeles' median income for renters increased only by 5.6 percent, compared with gains of 19.0 percent and 11.3 percent in San Francisco-Oakland and San Jose, respectively. Those Bay Area income trends cushioned the effects of rising rents and held down the growth in rent burden better than occurred in Los Angeles.

A number of widely accessible indicator systems have been developed to focus specifically on the number of renters with affordability needs, excluding issues of housing quality. In addition to the traditional rent burden indicator discussed previously, four more are surveyed here. This review is not exhaustive, but it includes the best-known alternatives.[7]

Review of Alternative Indicators

To incorporate the supply side in explaining rent burden, studies also have noted the gap between affordable supply and lower income demand (JCHS, 2018; Lens, 2018; NYU Furman Center, 2017). The "affordable supply gap" is measured by matching the volume of the affordable supply to that of demand from lower income renters. For example, in the case of extremely low-income renters (earning 30 percent or less of AMI), the gap is defined as the ratio of the number of extremely low-income renters to the number of rental housing units that would be affordable to those renters. Nationwide, for every 100 extremely low-income renter households, roughly 67 affordable rental housing units exist (NLIHC, 2018a). The advantage of the supply gap measure in describing rent burden is that it directly shows the shortage of the affordable supply relative to demand of a chosen group (Lens, 2018). The measure allows researchers to observe the full menu of options available to lower income groups rather than only the choices they actually make (Lens, 2018). That way, researchers can identify what the market is providing rather than calculate rent burden for households living in more expensive units when affordable units were occupied by others and not taken by the lowest income renters. This "supply gap" approach is very useful for targeting the needs of the poorest renters in the market area, but its findings can be distorted by the incursion of more advantaged renters into the most affordable supply.

Accordingly, this supply gap measure entails the use of optimal sorting, a conceptual construct that assumes that the lowest cost rental units are filled with the lowest income renters. Instead, it may fail to capture the nuances of the actual housing options for lower income households (Joice, 2014). Moreover, in large metropolitan areas, spatial distance may separate low-income renters from locations where the lowest cost units can be found. An extremely low-rent unit in a rural section of the Los Angeles metropolitan area is not a reasonable housing option for an extremely low-income household working in downtown Los Angeles. Furthermore, the measure of affordable supply gap may understate the severity of rental affordability because units are classified as affordable if they have gross rents that are affordable *at the top* of each income range (Collinson, 2011). In addition, in the competition for desirable affordable units, higher income households

7 Three additional candidates not discussed in-depth are of note. In 2016, HUD developed a new *Rental Affordability Index*, which measures whether the median renter household has sufficient income to qualify to lease a median-priced rental unit at the national level (HUD, 2016, 2018b). The index was designed to parallel the National Association of Home Builders' index of home purchase affordability. Although the new HUD index is available for every quarter since 2000, it is not included here because it pertains only to the nation as a whole. Since the early 1990s, HUD and the U.S. Census Bureau have been producing Comprehensive Housing Affordability Strategy (CHAS) data, which grantees receiving Community Development Block Grant and HOME program funds use to decide how to use the funds (HUD, 2015, 2018a). The CHAS relies primarily on ACS 5-year estimates to have the largest sample size and allow for the analysis of smaller geographies, such as city and township. Despite geographic fineness of the CHAS data, it is excluded here because main geographic area of our interest is metropolitan areas. Also useful but not included is the National Low Income Housing Coalition (NLIHC)'s *Housing Wage* indicator, which is an estimate of the hourly wage a full-time worker must earn to afford a rental unit at HUD's fair market rent without excessive rent burden (NLIHC, 2018b). NLIHC's indicator is excluded because it includes data only about renters who are full-time workers.

are more likely to be selected over lower income tenants, so affordable units actually occupied by higher income households may not be truly available to lower income households (Collinson, 2011; Joice, 2014).

Addressing that fault, several studies measured the availability of affordable rental housing to lower income households, with *available* defined as vacant or actually occupied by a household that is at or below the income threshold (Collinson, 2011; JCHS, 2018; Joice, 2014; NLIHC, 2018a). This actual availability of affordable housing is measured as the ratio per 100 of the number of lower income renters to the number of rental housing units that are both affordable and actually occupied by the group. When this availability dimension is applied, what was estimated as 67 affordable rental housing units per 100 extremely low-income renters is reduced to only 35 that are affordable and available (NLIHC, 2018a). Thus, the available supply of housing is much more limited than would be expected based only on price, and the affordability limitations are twice as great.

Rental affordability also has been measured in terms of balancing between housing cost itself and non-housing expenditures, such as food, transportation, health care, tax, and other necessities, within the constraints of household income (Stone, 2012). This "shelter poverty" approach improves rental affordability measures by showing tradeoffs between housing cost and other necessities. In this indicator, a household is considered "shelter poor" when the household has less "residual income" after allocating household income to housing expenses and thus has insufficient income remaining for necessary nonhousing expenditures. Risk of being shelter poor, therefore, largely depends on having low total income and on the size and composition of the household that determine nonhousing expenditure. As an example, in the Los Angeles metropolitan area in 2015, 67 percent of households with children were shelter poor, whereas, in the same place and time, only one-half of single-person households were shelter poor (Herbert, Hermann, and McCue, 2018).

Those specialized indicators of housing affordability provide useful insights, but they also require greater data detail than is commonly available. Moreover, they focus narrowly on the bottom rung of the housing market while neglecting the bulk of the rental market. Even though the problems of low-income renters deserve the greatest attention, the struggles of middle-income renters may produce competition that then brings added difficulties to lower tiers as would-be tenants scramble for more affordable options.

Comparison of Five Affordability Indicators

Exhibit 3 offers a systematic comparison of the distinguishing features of five alternative indicators of housing affordability: traditional rent-burden, supply gap, availability, shelter poverty, and the new constant quartile mismatch indicator.

Proportion Rent-Burdened. The traditional indicator is most widely used for reasons highlighted in the exhibit. It alone provides a single-number average of all renters' experience. It also has the easiest calculation and offers a very intuitive interpretation. This indicator, however, does not distinguish between rent and income causes of affordability problems, and it does not suggest how moderate- and higher income groups impinge on lower income renters. No solutions are suggested by the indicator's findings because so many factors are averaged together.

Exhibit 3

Conceptual Comparison of Alternative Indicators of Rental Housing Affordability

	Proportion Rent-Burdened	Affordable Supply Gap	Affordable Availability	Shelter Poverty	Constant Quartile Mismatch
Averages All Income and Rent Groups	Yes	No	No	No	No
Focused on Lower Income Renters	No	Yes	Yes	Yes	No
Links Across Income Groups	No	No	Yes	No	Yes
Distinguish between Rent and Income Effects	No	No	No	No	Yes
Time Emphasis	Present	Present	Present	Present	Change Since Baseline
Clarity of Graphic or Tabular Summary	Simple	Moderate	Moderate	Complex	Simple
Ease of Data Analysis	Simple	Complex	Complex	Very Complex	Moderate
Intuitive Understanding	Very Simple	Moderate	Moderate	Moderate	Simple
Problems Spotlighted	Average proportion of HH budget allocated to housing in an area	Shortages of low-income housing units needed to match number of low-income HHs	Shortages of low-income units greater when affordable units taken by mid- and higher income HHs	Deeper problems of the poor after rent payments deplete HH income	Growing mismatch between rent and income distribution in an area

Notes: HH = household. Highlighting signifies relative distinction of indicators. In the standard of "Focused on Lower Income Renters," two indicators marked "No" can still focus on a certain lower income group; however, general usage of the indicators is not focused on lower income groups, whereas that is always true for affordable supply gap and affordable availability indicators. Similar data sources (Census and ACS microdata files) are used for all indicators; the shelter poverty indicator requires additional data on nonhousing expenditures.

Affordable Supply Gap. This indicator has the benefit of focusing on the needs of lower income renters, matching the number of suitably priced rentals to their incomes. Its analysis is more complex, and public understanding is moderately intuitive. The spotlighted solution would be increased production of low-income housing.

Affordable Availability. Building on the supply gap measurement, this indicator adds the distinction of linking supply affordable to low-income renters to renters from competing income groups who could siphon off supply. Analysis is more complex, but the results are moderately intuitive. The spotlighted solution would be either producing a greater supply of affordable middle-income housing to lessen competition or increasing the supply of income-restricted housing aimed at very low-income renters.

Shelter Poverty. This indicator can be applied to all income groups, but its distinction is to show how rising housing costs make low-income renters, especially those with children, even poorer because their low incomes leave so little for other essentials. The spotlighted solution would be income assistance conditioned on household composition.

Constant Quartile Mismatch. This indicator, to be described fully in the next section makes implicit linkages across income groups because the quartiles sum to 100 percent. Another distinguishing feature is that it separately identifies rental cost shifts and income shifts, then combines them. Also distinctive is that the indicator is designed to measure changes over time, not single points in time as do the others, so it directly measures the changing affordability problem at four income levels. Analysis is moderately less complex than some of the others, and it features a more intuitive graphical display to enhance public understanding.

Method for Preparing the Constant Quartile Mismatch of Changing Affordability

The preceding review of alternative affordability indicators highlighted some limitations that could be addressed. The traditional measure of rent burden only expresses an average outcome for each geographic area. One problem is that we cannot tell whether rising affordability problems are concentrated at the bottom of the market or spreading into the middle. Another problem is the inability to determine whether rising rent burden is the result of higher rents, falling incomes, or both. Yet a third drawback of rent burden and other alternatives is that they tend to leave moderate- and higher income renters out of the picture. Residents who are voters and policymakers need to see their experiences reflected in measurements of housing affordability problems. Changes in the overall average or of only lower income renters do not allow most people to place themselves in the data picture. Some additional descriptive measurement could be helpful, particularly if it could be summarized in a simple and intuitive indicator.

Definition of Constant Quartiles

Given that complaints are not about the average but about the shifting distribution and relative access to rentals in different brackets, how might that be usefully summarized in a way that is easily comprehended? We propose a *constant quartile mismatch* (CQM) method for measuring the net results of this dynamic process of rent escalation over a number of years. If rents and incomes are broken into quartiles in a base year, we can use that metric to compare the distribution in a later year. Why quartiles and not quantiles with more numerous brackets, such as quintiles or deciles? Simplicity and intuitive understanding are a goal in this indicator design, and we wish to build on the familiar idea of the median rent. In addition, there are data considerations. For one, the American Community Survey, reported online through the Census Bureau's American FactFinder, reports upper (75 percent) and lower (25 percent) quartiles of housing expenditures in addition to the median (50 percent) but not quintiles or deciles. In addition, some dollar categories have very large entries that would require subdividing, creating unevenness, especially in smaller geographic areas. Quartiles have advantages for all those reasons.

Typically, the median rent and quartiles are redefined every year, but the twist in the new method is to hold those base year calculations constant, adjusting only for national inflation in the value of a dollar over time (exhibit 4). Every constant quartile break is assumed, therefore, to advance by the same percentage growth. For comparison, the final column shows the percentage change from 2000 to 2016 for the quartiles currently defined in 2016. In the case of income, that growth is higher for the top quartile, but all quartile increases are relatively similar to the pace of inflation. In the case of rents, however, the *current* quartiles have increased much more rapidly than has the pace of inflation that is used to define constant quartiles.

Exhibit 4

Quartile Breaks of Monthly Gross Rent and Annual Renter Household Income, Under Current and Inflation-Adjusted Constant Definitions, United States, 2000 and 2016

	2000	2016			
(a) Monthly Gross Rent					
	(a) Current Quartile	(b) Inflation-Adjusted Constant Quartile	((b - a) / a) x 100	(c) Current Quartile	((c - a) / a) x 100
	(2000$)	(2016$)	(% Growth)	(2016$)	(% Growth)
Break between Q3 and Q4	800	1,115	39.4	1,383	72.9
Break between Q2 and Q3	600	836	39.4	980	63.3
Break between Q1 and Q2	433	604	39.4	704	62.6
(b) Annual Renter Household Income					
	2000	2016			
	(a) Current Quartile	(b) Inflation-Adjusted Constant Quartile	((b - a) / a) x 100	(c) Current Quartile	((c - a) / a) x 100
	(2000$)	(2016$)	(% Growth)	(2016$)	(% Growth)
Break between Q3 and Q4	47,000	65,507	39.4	67,300	43.2
Break between Q2 and Q3	27,600	38,468	39.4	37,500	35.9
Break between Q1 and Q2	13,600	18,955	39.4	18,200	33.8

Notes: This study uses the U.S. Bureau of Labor Statistics (BLS) national annual consumer price index (CPI), which was 1.000 in 2000 and 1.394 in 2016, in relative terms. Universe is renter householders who pay cash rent, excluding renters paying no cash rent, approximately 5 percent of all renters. We use renter household income instead of household income to maintain the same universe for income and rent. Despite the large sample size of Census/ACS microdata, renters (or occupied rental units) were not evenly allocated into four quartile brackets in current quartile columns mainly because a large group of cases may be concentrated on a specific income (or rent) value, and its lump-sum allocation into a quartile bracket may result in slightly uneven distribution with adjacent quartiles.

Source: 2000 Decennial Census and 2016 American Community Survey IPUMS Microdata files (Ruggles et al., 2018).

Against this backdrop of inflation-adjusted, constant quartile breaks, the rental distribution in future years is sorted into the 2000-defined constant quartile categories. That shows, for example, how the number of units in 2016 in the bottom quartile are falling short of 25 percent, whereas those in higher quartiles may be exceeding their original 25-percent shares (exhibit 5). Identical calculations are carried out for renters' incomes so that the shift in incomes can be compared with

the shift in rents in the same metropolitan area. In our analysis, we use 2000 as the base year, representing the beginning of the new century and preceding the 2000s' economic boom, housing bubble, Great Recession, and struggling recovery. The decennial census data for 2000 are used to calculate the base year quartiles, and the most recent American Community Survey data are used to calculate the current distribution. (Inflation adjustment is carried out using the CPI.)

Exhibit 5

Quartile Income and Rent Distributions of Renter Households, Under Current and Inflation-Adjusted Constant Definitions, United States, 2000 and 2016

(a) Monthly Gross Rent								
	2000		2016					
	Under Current Quartile		Under Constant Quartile			Under Current Quartile		
	(a) Count	%	(b) Count	%	(b / a) %	(c) Count	%	(c / a) %
Highest Q4	8,356,389	24.8	16,266,421	39.1	94.7	10,375,113	25.0	24.2
Q3	8,327,994	24.7	9,972,394	24.0	19.7	10,261,485	24.7	23.2
Q2	8,565,453	25.4	8,206,528	19.7	– 4.2	10,527,036	25.3	22.9
Bottom Q1	8,416,777	25.0	7,108,692	17.1	– 5.5	10,390,401	25.0	23.4
Total	33,666,613	100.0	41,554,035	100.0		41,554,035	100.0	
(b) Annual Renter Household Income								
	2000		2016					
	Under Current Quartile		Under Constant Quartile			Under Current Quartile		
	(a) Count	%	(b) Count	%	(b / a) %	(c) Count	%	(c / a) %
Highest Q4	8,416,396	25.0	10,755,183	25.9	27.8	10,387,203	25.0	23.4
Q3	8,391,946	24.9	9,601,910	23.1	14.4	10,368,752	25.0	23.6
Q2	8,413,127	25.0	10,534,632	25.4	25.2	10,406,656	25.0	23.7
Bottom Q1	8,445,144	25.1	10,662,310	25.7	26.3	10,391,464	25.0	23.0
Total	33,666,613	100.0	41,554,035	100.0		41,554,035	100.0	

Notes: This study uses the national annual CPI, which was 1.000 in 2000 and 1.394 in 2016, in relative terms. Universe is renter householders who pay cash rent, excluding renters paying no cash rent, approximately 5 percent of all renters. We use renter household income instead of household income to maintain the same universe for income and rent. Despite the large sample size of Census/ACS microdata, renters (or occupied rental units) were not evenly allocated into four quartile brackets in current quartile columns mainly because a large group of cases may be concentrated on a specific income (or rent) value, and its lump-sum allocation into a quartile bracket may result in slightly uneven distribution with adjacent quartiles. Due to this lump-sum allocation and rounding at the second decimal place, percentages may not add to 100.0.

Sources: 2000 Decennial Census and 2016 American Community Survey IPUMS Microdata files (Ruggles et al., 2018).

Sensitivity Tests

The CQM method is especially sensitive to the choice of baseline year from which changes are measured. The year 2000 is convenient because it marks the beginning of the new century and also the decennial census year, but it also has practical significance. Sensitivity tests reported in appendix A indicate very different trends if 2006, near the peak of the boom and housing bubble, is selected for the base year. Rents had already begun climbing during the boom years, but incomes had declined among renters. That is likely a result of the boom in homeownership, which reached a record high of 69 percent in 2005, because many higher income renters were drawn into owning. Subsequently, after the financial crisis, when homeownership plunged, many would-be homeowners returned to renting, which raised the income levels again. That can be plainly seen in

exhibit A-1 in the appendix. Such volatility of boom and bust does not provide a stable context on which to place our baseline; using 2000 seems preferable.

A second matter of choice is which inflation factor to use for expressing the quartiles in constant dollars. One option is to use the most common choice, the CPI-U all items for urban consumers, which is based on the consumer choices of urban residents. A second option, suggested by a reviewer, is to consider the CPI "all items less shelter" costs. The two series track very closely until 2014, when there is a sharp departure (exhibit A-1). Although the CPI for "all items less shelter" has merit for measuring inflation of dollar values yet excluding rising housing costs, which is the subject of our analysis, the same deflator should also be used for incomes. Overall our sensitivity tests suggest that this alternative has a small effect of exaggerating the shift of rents into the top quartile (see exhibit A-2). The upward shift results from the abrupt decline in CPI for "all items less shelter" after 2014 so that the thresholds for upper quartiles are not raised as high as they are under adjustment by CPI for all items. Adjusting by CPI for "all items less shelter" creates lower thresholds, hence a greater upward shift in U.S. rentals into the top quartile, by 2 percentage points, whereas incomes similarly shift upward by 1 percentage point. We elect to retain the CPI for all items deflator because it produces more conservative estimates of change with the new constant quartile indicator.

Evidence from the Mismatch Indicator for Selected Metropolitan Areas

United States and Los Angeles

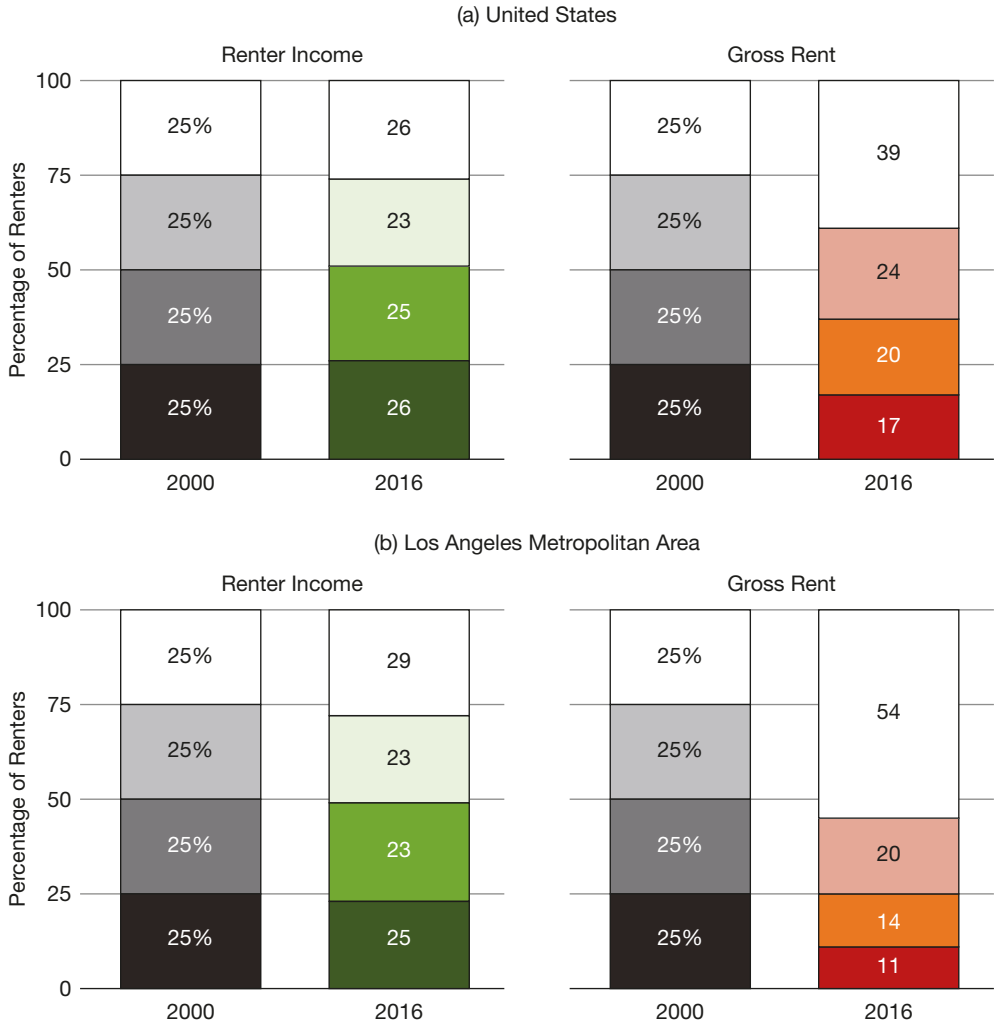
The results of the constant quartile calculations are demonstrated first for the United States as a whole and the Los Angeles metropolitan area, which illustrates an extreme case (exhibit 6). Rents have shifted upward in the United States, with 39 percent of renters paying rents in 2016 that were formerly in the 25 percent top bracket (Q4). Conversely, the share with bottom bracket rents has declined from 25 percent to 17 percent (Q1). On the income side, very little change has occurred, with one extra percentage-point share of renters in both the top and bottom income brackets. Rents have clearly increased relative to incomes of renters in the nation.

Greater changes are observed In Los Angeles, as expected. More than one-half the renters (54 percent) are now paying rents in the traditional top bracket, which was formerly occupied by only 25 percent. Conversely, the shares paying rents in the traditional bottom brackets (below the median) have fallen to 11 percent (Q1) and 14 percent (Q2).

The severe upward shift in rents in Los Angeles might not be a problem if the income distribution of renters also shifted upward. As also shown in exhibit 6, however, the share of renters in the two bottom brackets remains virtually the same as before. Meanwhile, the share in the traditional highest income bracket for Los Angeles metropolitan area renters has expanded moderately to 29 percent, an increase of 4 percentage points, not enough to keep up with the extremely large increase in the share now paying top-level rents. This reflects a slight income polarization in Los Angeles, where the share in the middle two income quartiles declined by a total of 4 percentage points.

Exhibit 6

Quartile Distribution of Renter Households by Income and Rent, Under Inflation-Adjusted Constant Quartile Breaks, 2000 and 2016, United States and Los Angeles Metropolitan Area (unit: percentage share)



Note: Percentages may not add to 100 due to rounding at the first decimal place.

Sources: 2000 Decennial Census and 2016 American Community Survey IPUMS Microdata files (Ruggles et al., 2018).

Metropolitan Areas with Rising Incomes

The anomaly of more affordable housing in the San Francisco Bay Area was addressed earlier with regard to the rent burden indicator. Higher incomes were believed to be the cause, even though rents were substantially higher. Here we compare the constant quartile mismatch results for San Francisco, San Jose (Silicon Valley), and the Washington, D.C., area, the seventh largest region in

the United States, which also is experiencing rising incomes. All areas with rising renter incomes also have rising rents, some more so than others.

The separate effects on housing affordability of rental price increase and income growth are well represented by the constant quartile indicator of housing affordability. Exhibit 7, panel (a), displays the changes recorded between 2000 and 2016 in the selected economically thriving metropolitan areas, San Francisco-Oakland, San Jose, and Washington, D.C. Rents shifted upward in all three, swelling the share paying rents in the traditional top quartile to 49 percent, 49 percent, and 58 percent, respectively. In the same time frame, incomes also rose in these growing metropolises, with the share of renters in the traditional top income quartile rising to 34 percent, 32 percent, and 31 percent, respectively. Thus, some of the upward skew in rents is offset by an upward shift in incomes. The Washington metropolitan area's 33 percentage-point shift of rentals into the top quartile, less the 6 percentage-point shift of incomes into the top quartile, exceeds all others of the 50 largest metropolitan areas.

In addition, all three of these metropolitan areas display signs of a hollowing out of the two middle-income quartiles, whereas the bottom quartile retains close to its original share in San Francisco-Oakland but swells in size to 27 percent in Washington and 29 percent in San Jose. A sign of stress in the lower income bracket is that the share of rentals available in the bottom price bracket has decreased far below the income share in the bottom bracket. In San Francisco-Oakland, the rental share of 16 percent is 8 percentage points lower than the income share of 24 percent, whereas in San Jose the gap widens to 12 percentage points. In Washington, the shortfall between the rental and income share in the bottom quartile reaches 15 percentage points.[8]

Metropolitan Areas with Stable Incomes and Rising Rents

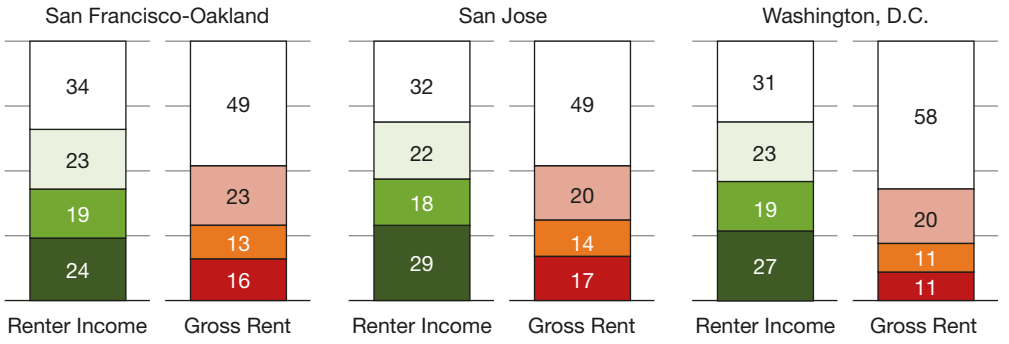
Most metropolitan areas do not have the upward income shifts of the areas just discussed. More representative may be Buffalo, Pittsburgh, and Miami, where the share in the top income quartile held steady, similar to the national average, at about 25 percent in 2016, showing no change since 2000 (exhibit 7, panel [b]). What varies among these three is the changing share in the *bottom* income quartile, ranging from a growing low-income share in Buffalo (27 percent) to a falling share in Pittsburgh (23 percent) and Miami (22 percent).

8 Appendix B of this article reports the exact differences.

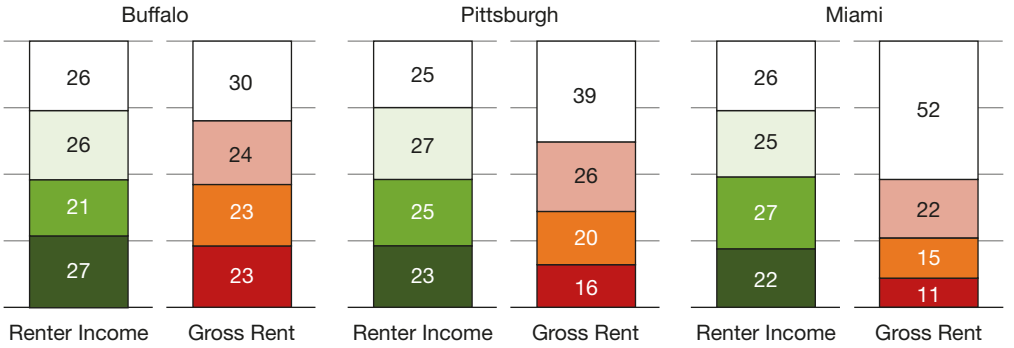
Exhibit 7

Comparisons of Quartile Distribution of Renter Households by Income and Rent, Under Inflation-Adjusted Constant Quartile Breaks, Selected Metropolitan Areas, 2016 (unit: percentage share)

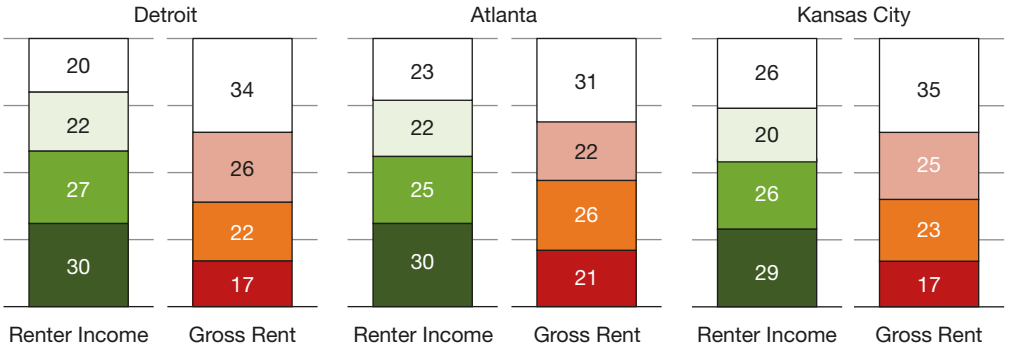
(a) Metropolitan areas where incomes are growing, while rents are growing even faster



(b) Metropolitan areas where incomes are stable, while rents are rising



(c) Metropolitan areas where incomes are falling, but rents are rising



Notes: Reference quartile distribution of 2000 was omitted for simplicity. Percentages may not add to 100 due to rounding at the first decimal place.

Sources: 2000 Decennial Census and 2016 American Community Survey IPUMS Microdata files (Ruggles et al., 2018).

Affordability problems are suggested by the upward shift in rents relative to income gains. Buffalo reveals only a slight upward shift, whereas Pittsburgh and Miami experienced sharp upward shifts into the top rental bracket. The gap between the rental and income shares in the top quartile in Buffalo is only 4 percentage points, whereas in Pittsburgh it is 14 points and in Miami 26 points (exhibit 7, panel [b]). The extreme rental shift in Miami, unaccompanied by income rise, is indicated also in the bottom two quartiles, where rentals below the former median accommodate only 26 percent of renters, while at the same time, in terms of income, 49 percent of renters remain below the former median. This extreme shift of rentals versus incomes in Miami is what has led to the Miami metropolitan area having the highest incidence of excessive rent burden of any large metropolitan area in the United States (61.2 percent with excessive rent burden and 34.0 percent with severe rent burden; see also exhibit 2 and appendix B).

Metropolitan Areas with Declining Incomes and Rising Rents

The final set of metropolitan areas compared is characterized by declining incomes at the same time as the metropolitan area is experiencing rising rents, a combination that potentially could lead to even greater affordability problems (exhibit 7, panel [c]). Here we compare Detroit and Atlanta, in each of which the income share declined in both of the two highest quartiles whereas the income share increased in the bottom quartile. Kansas City, which has more stable income—although less so than Buffalo, previously compared—also experienced declines in the middle and growth at the bottom. Against this shift in incomes, we compare the upward shift in rents, which grew more in the top rental bracket than did the top income quartile, a gap of 8 points in Atlanta and 9 points in Kansas City, and a gaping 14 points in Detroit. In all three of these metropolitan areas, a smaller share of rentals remained available in the bottom quartile than the share of renters whose incomes were in the bottom quartile. Again, the greatest disparity is found in Detroit, where the share of rentals that are low priced is 13 percentage points smaller than—practically one-half—the share of low-income renters. Kansas City also has a 12-point disparity in the bottom quartile to offset its rent and income growth in the top quartile.

It bears mentioning that severe racial geographic segregation within the metropolitan region, exemplified by the Detroit case, might lead to growth of high-end rentals in suburban areas at the same time as the overall rental population shrinks in the top income quartile and grows in the bottom, especially in central cities. A similar pattern of spatially polarized rental markets, although likely less extreme, could be at work in other metropolitan areas, but that subject is beyond the scope of the present work.

These case examples of changing rents and incomes provide a richer description than is revealed by the simple average incidence of rising rent burden. Here we see how the shifts in incomes and rents have not worked in tandem, with different patterns of stress and strain emerging in each of our case examples. Using the constant quartile mismatch indicator produces a distinct profile of affordability change for each city. Complete details for every metropolitan area are supplied in appendix B.

Correlations of Quartile Changes with Growing Rent Burden

The preceding profiles provide more detailed insights for each metropolitan area, but how well do they correspond to the overall incidence of excessive rent burden—the traditional measure of housing affordability? A one-to-one correspondence might imply no need for an indicator different from the traditional rent burden. On the other hand, any indicator that does not generally increase with average rent burden would have a difficult task to establish its credibility. Ideally a new indicator would convey information about affordability that is akin to rent burden affordability but sufficiently novel in its details and perspective added.

The correlation between the two measures can be compared in different ways (exhibit 8). The previous discussion emphasized disparities in the top quartile of rents and incomes. Growth in that quartile indicates an upward shift that corresponds to declines in lower quartiles. The larger the gap between the growing rent and income shares in the top quartile, the greater the increase in incidence of excessive rent burden averaged across all renters ($r = 0.62$). Alternatively, the gap in the bottom quartile between changing rent and income distributions might be more meaningful for the affordability experience of low-income renters. In fact, this bottom quartile gap in each metropolitan area correlates even more strongly with the increase in average incidence of rent burden when compared across the metropolitan areas ($r = -0.73$).

Exhibit 8

Correlations between Rising Incidence of Excessive Rent Burden and Changes in Alternative Constant Quartiles, 2000 to 2016

	Net Increase in Total Rent Burden (30%+)	Net Increase in Severe Rent Burden (50%+)
(a) Rent Q4	0.38	0.39
(b) Rent Q4 - Income Q4	0.62	0.56
(c) Rent Q1	– 0.49	– 0.42
(d) Rent Q1 - Income Q1	– 0.73	– 0.70
(e) Rent (Q1 + Q2)	– 0.43	– 0.40
(f) Rent (Q1 + Q2) - Income (Q1 + Q2)	– 0.76	– 0.67

Sources: 2000 Decennial Census and 2016 American Community Survey IPUMS Microdata files (Ruggles et al., 2018).

When only rental quartiles are correlated, without comparing income changes, a much weaker fit is found with the incidence of rent burden (exhibit 8). For example, the correlation with shifts of rentals into the top rent quartile has a much lower correlation ($r = 0.38$) with overall incidence of rent burden than when the income shift is subtracted ($r = 0.62$), for reasons previously discussed. Without adjustment for rising incomes, we would expect a much higher incidence of excessive rent burden in San Jose, for example, than is observed.

Among all the correlations compared in exhibit 8, there is little difference between correlations with total excessive rent burden or, alternatively, incidence of severe burden. As noted earlier, in discussion of exhibit 2, severe burden generally increases proportionally with total burden, so it sustains the same correlation.

In general, this analysis shows that the constant quartile indicator bears a close relation to the traditional indicator of excessive rent burden. Depending on the degree of income change and rent increases, the bottom quartile could prove a more useful measure of local changes than does the top quartile. For the most part, however, the top quartile is the one that is growing for rentals and sometimes incomes, and this expanding high-rent segment is the focus of concerns about rising rents, gentrification, and neglect of opportunities for lower income renters. Nonetheless, a closer comparison is warranted between the top and bottom quartiles in each metropolitan area.

Affordability Mismatch at the High or Low End

Affordability can worsen in a metropolitan area because of either a growing mismatch at the top of the rental market, with more rentals added in the top bracket than renters are added to the top income quartile, or a growing mismatch at the bottom, with more rentals lost from the traditional lowest quartile price bracket than renters are lost from the lowest income bracket. Some metropolitan areas may suffer growing mismatches at both ends, whereas others have little change at either the top or bottom. In this section, we assess those differences and rank the metropolitan areas according to their degree of affordability mismatch at different price levels. All those assessments are made relative to the metropolitan area's historical balance of rents and incomes, as reflected in the constant quartiles calculated for 2000 and then carried forward to compare changes in housing opportunities observed in 2016.

Given that the shares of rentals in the four quartiles are designed to sum to 100 percent, any redistribution to the top quartile must come out of the lower quartiles. In principle, gains at the high end should be directly correlated with losses below, and vice-versa. Changes in the two middle quartiles are ambiguous, however; they can come from exchanges either above or below. In fact, the middle quartiles serve as a buffer between changes at the high or low end. For that reason, we judge only the affordability mismatch at the two extremes, the top and bottom quartiles. The assumption is that any mismatch in the bottom (or top) quartile is accommodated by drawing rentals or renter households from the middle two quartiles.

In fact, the mismatches at the top and bottom ends of the rental market are not tightly correlated ($r = 0.48$). Some metropolitan areas have distinct shortages of rentals in the bottom rent quartile compared with their share of renters in the bottom income quartile. Other metropolitan areas have large surpluses in the top rental quartile relative to their share of renters in the top income quartile. Still other metropolitan areas have greater depletion from the two middle quartiles to feed the growth at the high or low end, thus the high and low gains or losses are not directly connected, even if partially correlated.

A summary of the least affordable and most affordable metropolitan areas is compiled on the basis of mismatches observed at the high or low end of the rental distribution, or both (exhibit 9). This produces three different lists. First is the high-end mismatch formed of an excess of high-cost rentals relative to high-income renters. Three of the 10 worst mismatches are in the regional vicinity of Washington, D.C., (D.C. metro, Virginia Beach, and Baltimore). Another three are in southern California (Los Angeles, San Bernardino-Riverside, and San Diego). The remaining metropolitan areas are New Orleans, Miami, New York, and Denver.

Exhibit 9

Constant Quartile Affordability Mismatch at High and Low End of Rental Housing Markets in the 50 Largest Metropolitan Areas, Changes from 2000 to 2016 (unit: percentage point changes)

IN ORDER OF HIGH-END MISMATCH			IN ORDER OF LOW-END MISMATCH			IN ORDER OF TOTAL MISMATCH		
Pop Size Rank	Metro Name	(a) High-end Mismatch	Pop Size Rank	Metro Name	(b) Low-end Mismatch	Pop Size Rank	Metro Name	(c = a + b) Sum of Mismatch
10 Least Affordable Metropolitan Areas (Highest Score)								
7	Washington, D.C.	26.9	43	Richmond	15.3	7	Washington, D.C.	42.1
13	Riverside-SB	26.5	41	Memphis	15.2	17	San Diego	39.8
46	New Orleans	25.9	7	Washington, D.C.	15.2	36	Virginia Beach	38.9
17	San Diego	25.6	5	Houston	15.2	2	Los Angeles	38.6
8	Miami	25.2	36	Virginia Beach	14.5	13	Riverside-SB	36.6
2	Los Angeles	25.2	40	Jacksonville	14.3	46	New Orleans	36.4
36	Virginia Beach	24.4	17	San Diego	14.3	8	Miami	36.3
20	Baltimore	24.0	25	Sacramento	14.0	21	Denver	35.8
1	New York	23.6	39	Milwaukee	13.8	5	Houston	34.3
21	Denver	23.0	2	Los Angeles	13.5	25	Sacramento	33.6
10 Most Affordable Metropolitan Areas (Lowest Score)								
29	Kansas City	9.7	37	Providence	7.7	44	Oklahoma City	20.5
14	Phoenix	9.5	49	Salt Lake City	7.3	49	Salt Lake City	20.0
30	Las Vegas	9.5	10	Boston	7.1	32	Columbus	19.4
32	Columbus	9.2	42	Louisville	7.0	27	Cincinnati	17.9
27	Cincinnati	8.8	22	Pittsburgh	7.0	14	Phoenix	17.9
9	Atlanta	8.3	50	Birmingham	6.8	9	Atlanta	17.2
39	Milwaukee	6.8	30	Las Vegas	5.5	30	Las Vegas	15.0
28	Cleveland	4.7	44	Oklahoma City	5.4	28	Cleveland	12.5
47	Raleigh	3.7	48	Buffalo	4.7	48	Buffalo	8.3
48	Buffalo	3.6	47	Raleigh	3.0	47	Raleigh	6.6
	Total United States	13.3		Total United States	8.6		Total United States	21.8
	50 Metro Average	16.2		50 Metro Average	10.5		50 Metro Average	26.7
	Standard Deviation	6.2		Standard Deviation	3.1		Standard Deviation	8.1

Notes: Pop = population; metro = metropolitan area; SB = San Bernardino; high-end mismatch measured as the share of rentals added in top quartile less share of renter incomes added in top quartile; low-end mismatch measured as the share of rentals lost in bottom quartile less share of renter incomes lost in bottom quartile.

Sources: 2000 Decennial Census and 2016 American Community Survey IPUMS Microdata files (Ruggles et al., 2018).

The second list contains the mismatch formed of a shortage of low-priced rentals relative to their numbers of low-income renters. The least affordable metropolitan areas on the low-end mismatch have some overlap with the high-end mismatch but also include Richmond, Memphis, Houston, Jacksonville, Sacramento, and Milwaukee. Finally, summing the low and high-end mismatches, the third list reports a combined score that summarizes the overall *least affordable* metropolitan areas, with Washington, D.C., the clear leader (exhibit 9 and appendix B). Los Angeles is fourth worst, and Miami, the metropolitan area with the highest average incidence of rent burden (exhibit 2), was only seventh worst.

Conversely, at the bottom of exhibit 9 is a listing of the *most affordable* metropolitan areas, those with the least mismatch between rents and incomes. Buffalo and Raleigh are the clear leaders. In the remainder of the 10 most affordable at the high end, midwestern metros dominate: Cleveland, Milwaukee, Cincinnati, Columbus, and Kansas City. Filling out the list are Atlanta, Las Vegas, and Phoenix. Milwaukee is notable for the highly polarized outcome of making the list of most affordable metropolitan areas at the high end while simultaneously entering the top 10 for *least* affordable when assessed at the low end. Its burgeoning low-income population is simply not matched by an adequate supply of rentals in the bottom quartile.

In fact, none of the midwestern metropolitan areas make the list of most affordable when judged with respect to mismatches in the bottom bracket. Instead, four southern cities are most prominent (Raleigh, Oklahoma City, Birmingham, and Louisville), accompanied by four in the northeast (Buffalo, Pittsburgh, Boston, and Providence). Salt Lake City and Las Vegas complete the list. Las Vegas is most notable because its share of rentals in the bottom quartile held steady; it was the only metropolitan area among the 50 largest that avoided shrinkage in supply in the bottom price bracket (see appendix B).

When the housing demand and supply mismatches at the high and low end are summed, the most affordable metropolitan areas overall are led by Raleigh and Buffalo, followed by Cleveland, Las Vegas, Atlanta, and Phoenix. Next on the list are two more Ohio cities, Cincinnati and Columbus, followed by Salt Lake City and Oklahoma City (exhibit 9).

The Use of Affordability Indicators

Housing affordability must be measured by multiple indicators because each has a different emphasis in what it measures. It is a truism that there is no national housing market, because all housing markets are local, where workers and other residents shop for housing. Local differences among cities and neighborhoods provide a diversity of opportunities, but those are bound together by substitutability of local housing units within a metropolitan region, or rural and small-town commuting area, as consumers comparison shop for the best home in the best neighborhood at the best price, subject to income constraints and their particular preferences. Certainly affordability indicators should be applied to subareas within regions, but overall differences in affordability are expressed at the metropolitan scale.

Regional planning directors, working through metropolitan planning organizations (MPOs), may have the most complete view of providing housing to meet the needs of workers and the rest of the

Exhibit 10

Summary of Constant Quartile Mismatch and Other Rental Affordability Measurements Available in 2016, United States and Selected Metropolitan Areas

	United States	West		Midwest		South		Northeast	
		Los Angeles	SF -Oakland	Detroit	Kansas City	Atlanta	Washington, D.C.	Pittsburgh	New York
Proportion Rent-Burdened (2016)									
% Excessive Rent Burden (30%+)	47	57	46	49	43	47	46	41	51
% Severe Rent Burden (50%+)	25	32	24	27	20	23	24	22	29
Affordable per 100 Renters (2016)									
Very Low-income (<50% of AMI)	72	39	73	70	92	56	67	97	57
Affordable/Available per 100 Renters (2016)									
Very Low-income (<50% of AMI)	47	28	51	47	58	36	45	60	41
Constant Quartile Mismatch (2000 to 2016)									
Top Quartile									
(a) Rent Increase *	14	29	24	9	10	6	33	14	26
(b) Income Increase *	1	4	9	– 5	1	– 2	6	0	2
(c = a - b) Difference	13	25	15	14	10	8	27	14	24
Bottom Quartile									
(d) Rent Increase	– 8	– 14	– 9	– 8	– 8	– 4	– 14	– 9	– 9
(e) Income Increase	1	0	– 1	5	4	5	2	– 2	– 1
(f = d - e) Difference	– 9	– 13	– 8	– 12	– 11	– 9	– 15	– 7	– 8
Top and Bottom									
(g = c - f) Difference Combined **	22	39	23	26	21	17	42	21	32

*Notes: * "Increase" is calculated as the quartile share in 2016 less the initial 25 percent share in 2000. ** "Combined" is calculated as top quartile difference minus bottom quartile difference. AMI = area median income. SF = San Francisco. Percentages may not match due to rounding at the first decimal place. For the purpose of comparison, we calculated indicators of affordable supply gap and availability of low-cost rentals with a focus on very low-income renter households (less than 50 percent of AMI) because they are the primary target population of major federal rental assistance programs. Household and housing unit size adjustments and physical adequacy of units were omitted in calculating indicators of affordable supply gap and availability both for simplicity and to maintain comparability with constant quartile mismatch and rent burden indicators. Shelter poverty indicator was not included in this comparison because of the complexity of its calculation, as previously discussed in exhibit 3.*

Sources: 2000 Decennial Census and 2016 American Community Survey IPUMS Microdata files (Ruggles et al., 2018).

growing population in metropolitan areas. That will of course require gaining the cooperation of a host of constituent city and county jurisdictions and the local citizens. How might metropolitan-level analysis with different indicators of housing affordability assist a hypothetical set of MPO directors as part of their planning toolkit?

To illustrate the set of choices and implications, we have assembled a set of data findings collected through the alternative indicators surveyed earlier in the article. Exhibit 10 summarizes the menu of indicator results available to MPO directors, reporting current data for eight example metropolitan areas, two from each of the four major census regions.

To begin, the *rent burden* indicator shows that in every metropolitan area, nearly one-half of renters carry excessive rent burden and one-fourth carry severe burden, with all metropolitan areas reasonably close to the national average. That might lead any metropolitan area planning director to believe that affordability is a national problem and not due to any particular circumstances in his or her region. Looking more closely, however, Kansas City and Pittsburgh seem to be substantially more affordable, whereas Los Angeles stands out as having a very high incidence (57 percent) of excess rent burden. The credibility of measurements in other metropolitan areas, however, may be undermined when local citizens see their region listed as slightly more affordable than the U.S. average. Residents in San Francisco-Oakland or Washington, D.C., might find their regions' 46-percent rent burden incidence curiously deceptive relative to the nation's 47 percent. As discussed previously, failure to distinguish income and rent effects in this indicator is what distorts the appearance of affordability. Also, as previously reviewed, the overall average given by the rent burden indicator may not describe the experience of specific income groups.

MPO planning directors should view information targeted to very low-income renters (earning less than one-half of their area median income) because that group often is the most vulnerable and deserves close attention. The *supply gap* indicator measures the ratio between the number of low-income renters and the number of units affordable to renters of that income. Tracking that supply gap indicator would be very worthwhile. Not all that supposed "low-income" supply is available for occupancy by low-income renters, however. Much of it may be occupied by renters of somewhat higher income who are paying lower shares of their income in more affordable homes. The *supply availability* indicator measures the ratio of low-income units available for low-income occupancy after subtracting any higher income tenants. Among the metropolitan areas summarized in exhibit 10, Los Angeles fares far below the national average in low-income supply (only 39 units per 100 very low-income renters) and availability (28), compared with U.S. figures of 72 and 47, respectively. In contrast, low-income renters in Kansas City and Pittsburgh have much more available supply. Again, however, San Francisco-Oakland seems remarkably average, whereas the Washington, D.C., metropolitan area is only slightly below average. A surprising metropolitan area on this indicator is Atlanta. Despite its incidence of rent burden matching the national average, the Atlanta metropolitan area's supply availability is only 36 per 100 very low-income renters, which may be better than Los Angeles but not better than the rest of the selected metropolitan areas, including New York. A hypothetical MPO director in Atlanta should see this indicator as evidence for high-priority attention to the lowest income renters.

Turning now to the insights derived from the *constant quartile mismatch* indicator, the MPO directors will want to learn how well supply has kept up with needs in the market as a whole, including broad price brackets. Any shortfalls, particularly at the low end, could be the root of very low supply availability and high incidence of excessive rent burden in the metropolitan area. Changes in the top quartile, however, also are crucial to monitor because they spotlight metropolitan area-wide affordability problems that are created when more renters are forced into the traditional highest rental bracket. The shift of rentals into the top bracket puts pressure on the rest of the pyramid of rentals, both as tenants search downward for more affordable deals and as landlords look upward at rising rents as a signal for increases in lower brackets as well. Ill effects ripple downward from growth in the top quartile, as shortages of housing affordable to moderate- and middle-income renters may cause them to scavenge downward into housing submarkets formerly occupied by very low-income renters. That search is a factor that drives down the actual low-income availability indicator below what is estimated by the indicator of low-income supply gap. It also is a prime driver of gentrification.

Exhibit 10 provides more details for the constant quartile mismatch indicator because it holds information about rents and income trends (and graphic displays of data for specific metropolitan areas can be seen in exhibits 6 and 7). Different sources of the rental affordability problem are revealed by the CQM method in different metropolitan areas. In the case of Detroit—and to a lesser extent, Atlanta—the share of renters in the top income quartile is declining, whereas that in the bottom is growing. Despite that income decline, the share of rentals in the top price quartile has increased, whereas rentals in the bottom quartile have decreased. It is the combination of income declines and opposing trends of rents that generates Detroit's rental affordability problem. Atlanta resembles the polarized Detroit changes, but only to about one-half the degree. Solutions will have to include economic development programs to boost incomes and seek to improve supply in the middle and lower quartiles.

Conversely, the San Francisco-Oakland metropolitan area demonstrates another route to exacerbating affordability problems, witnessed also in Washington, D.C., and Los Angeles. San Francisco has experienced a very large increase (9 percentage points) in the income share in the top quartile, with little change in the bottom. Similar change is witnessed in Washington (+6 points) and Los Angeles (+4 points). Those income gains partially offset the very large shift of rentals into the top price bracket. The upward shift in the Washington metropolitan area is most extraordinary (+33 points, more than doubling the share of renters in the top quartile, from 25 percent to 58 percent), followed by Los Angeles (+29 points) and San Francisco (+24 points). Such rapid increases in rents, far in excess of the upward shift in income, suggests that the MPO directors should evaluate their regions' rate of supply increase relative to the rate of demand growth. Given the cumulative deficits of construction that cause supply to lag so far behind housing needs, MPOs should deliberate whether it is possible to accommodate greater economic growth in the future without drafting some kind of catchup plan. In that light, it seems essential for housing programs to coordinate with economic development programs.

These insights about housing shortage amid prosperity are not visible through the other affordability indicators. Los Angeles might seem to be a lone, harsh anomaly, with its high average

rent burden that does not represent a pattern followed by others outside southern California, save for Miami. Before we accept that the San Francisco and Washington metropolitan areas are actually more affordable than average for the nation, however, the CQM findings on the growing mismatch of rents and incomes bear consideration. The combined mismatch of incomes and rents, summing the shifts into the top and out of the bottom quartile,[9] is 42 percent for the Washington area, edging past Los Angeles at 39 percent and far surpassing Kansas City and Pittsburgh with 21 percent, which closely resemble the national average of 22. Taking the bottom quartile separately, the greater outflow of rentals than low-income households measures stress at the bottom of the rental market. On this, Washington and Los Angeles still lead in exhibit 10, and they are well above the national average. In contrast, the strong shift of rentals into the top quartile reflects stress at the top of the rental market, particularly for the former occupants of the middle quartiles who now must pay traditional top quartile rents. Again, we find that Washington and Los Angeles are major leaders in affordability stress, even after subtracting the smaller upward shift in incomes.

A final observation for the MPO directors is the potential organizational use of the CQM indicator findings. Those findings broaden the scope of housing affordability to reflect stresses also afflicting moderate- and middle-income renters, not solely the very low-income renters. Sharing that indicator with the public and with leaders of member jurisdictions also helps illustrate how all segments are linked together as rent distributions shift over time. As a whole, the constant quartile mismatch indicator underscores that the problem of shortage and reduced affordability afflicts all renters in the region, much more so in some regions than in others. The graphic display that accompanies the indicator (as in exhibits 6 and 7) may assist MPO directors in improving public understanding about the breadth of the affordable housing crisis and thereby help build the public will to support greater construction to meet growing housing needs.

Conclusion

Housing affordability has been growing as a problem, only recovering slightly from setbacks during the bubble and after the recession. Solutions will require local-level acceptance of the need for more construction and greater subsidies targeted to very low-income renters (Schwartz, 2015). Indicators of housing affordability are useful for measuring the growing problems and for comparing places. Although the indicators do not substitute for detailed market studies or technical causal models, they are simplified constructs that are essential for directing attention and assisting popular communication about the extent of the affordability problem. In this simplified use, the crucial criterion is that indicators must not be misleading. That quality is best judged through comparisons of multiple metropolitan areas so that users can better understand the implications of different indicators.

The traditional rent burden indicator, which is the most commonly used indicator of rental affordability, finds that nearly one-half (47.5 percent) of renters in America are spending more than 30 percent of income on rent. The great majority of large metropolitan areas (45 of 50) fall within

9 As noted previously, this is not a double counting of shifts, under the assumption that the middle two quartiles form a buffer that absorbs the exits from the bottom quartile and serves as the origin of shifts into the top quartile. The end results at the two quartiles at the extremes reveal how the effects of mismatch register.

8 percentage points, plus or minus, of this national average prevalence of excessive rent burden. On this indicator, few seem substantially more affordable than average. In addition, because this indicator is an average of all renters in the area, it may not highlight well the experience of renters at either the low or high end of the housing market. In addition, the inability of the traditional indicator to distinguish between rent and income effects can be misleading about the sources of affordability problems. That leads to anomalous findings that the San Francisco Bay Area or the Washington, D.C., metropolitan area is more affordable than the national average. Other less popularly used indicators, such as the low-income supply gap or shelter poverty indicators, are much more successful in highlighting low-income housing affordability problems. Those indicators, however, are more complex, and they also neglect the middle and higher ranges of the rental market.

The CQM indicator proposed here offers an alternative view on rental affordability, emphasizing middle-income as much as very low-income renters and recording the cumulative changes over time. The indicator measures shifts in rent and income from their traditional distribution prevailing in 2000, preceding disruptions of the housing bubble and bust, the Great Recession, and the prolonged recovery. With this indicator we explain the San Francisco and Washington anomalies of low rent burden by virtue of income gains that partially offset the effects of the upward rent shifts. Under the CQM formulation, even with income adjustment, both metropolitan areas are found to have affordability problems that are greater than the national average. In fact, Washington, D.C., which has suffered an acute loss of rentals from the bottom quartile and has more than doubled its rentals in the traditional highest rent quartile, tops the mismatch list of least affordable large metropolitan areas.

Each area has its own profile of affordability under the CQM indicator, as shown in the CQM graphic display (as in exhibits 6 and 7) that parallels changes in rent and income distributions side by side, anchoring both at the beginning of the new century. Dividing the distribution into quartiles allows residents to place themselves in this picture of change. Metropolitan areas with more acute affordability pressures feel strain at all levels of the distribution. Representing that graphically and with specific summary figures may help the public and elected leaders grasp the comprehensive scope of growing affordability strains and how broad-based must be the solutions.

Further research is possible with the constant quartile mismatch indicator of affordability, which can easily be adapted for analysis of smaller areas, such as counties, cities, and neighborhoods. Researching the conditions that cause the CQM indicator to take on higher or lower values would also be valuable. It is not known how large an increase in rental supply is needed to move the index downward in a short time or what difference it makes if new housing is added in the middle of the market in place of the bottom. Conversely, it would also be useful to learn how big an effect a large employment increase, without commensurate new housing additions, would have on the CQM and other rental affordability indicators. In general, much can be gained by using the indicator to highlight answers to practical questions that are of importance to local decision makers or the public.

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Appendix A. Sensitivity Analysis of Constant Quartile Mismatch Indicator

Our constant quartile mismatch measure relies on assumptions that may affect end results. This appendix tests two major factors: choice of Consumer Price Index (CPI) and base year of quartile measurement.

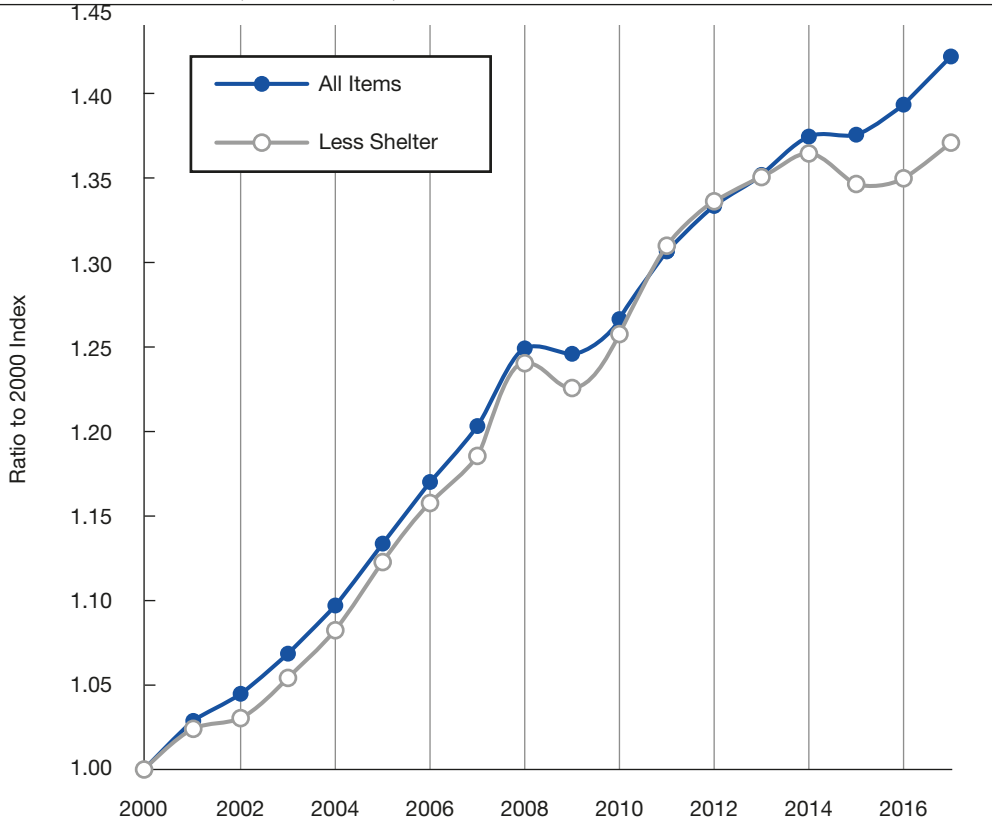
Choice of Consumer Price Index

Constant quartile mismatch measure is based on the broadest and most comprehensive CPI reported in the media, which is officially referred to as the All Items Consumer Price Index for All Urban Consumers (CPI-U) for the U.S. City Average, not seasonally adjusted, 1982–1984=100 (Bureau of Labor Statistics, Consumer Price Index Website). An alternative to be considered is CPI on all items less shelter, which reflects inflation of all item prices except housing cost. The Bureau of Labor Statistics explains the use of alternative CPIs as such: "In addition to the all items index, BLS publishes thousands of other consumer price indexes, such as all items less food and energy. Some users of CPI data use this index because food and energy prices are relatively volatile, and they want to focus on what they perceive to be the 'core' or 'underlying' rate of inflation." In measuring rental affordability, CPI all items less shelter can be a reasonable alternative because rents were very volatile between 2000 and 2016, and we can focus on rate of inflation that is separate from what we are trying to analyze.

Exhibit A-1 shows that the trajectory of CPI on all items less shelter is generally lower since 2000 than that of all items, except the early recovery period (2011 and 2012). In contrast, CPI on all items is much higher than CPI on all items less shelter in the most recent years after 2014. That divergence clearly reflects that housing cost led overall inflation in the most recent years, and it justifies use of CPI on all items less shelter as an alternative in our analysis. What if we use CPI on all items less housing cost instead of CPI on all items?

Exhibit A-1

Bureau of Labor Statistics' Consumer Price Index (CPI) Based on All Urban Consumption Items and All Less Shelter Cost, United States, 2000 to 2017



Source: U.S. Bureau of Labor Statistics, Consumer Price Index Database.

Exhibit A-2 shows that our original measure, based on CPI all items (panel a), results in weaker shifts of renters and rental units toward higher end brackets than CPI all items less shelter (panel b). It is not surprising because CPI all items is higher than CPI all items less shelter in 2016 (as shown in exhibit A-2), which then raises income and rent quartile breaks ($ value) to higher level, and consequently fewer renters in 2016 are allocated into higher income and rent brackets. In sum, our original constant quartile measure based on CPI all items can be seen as more conservative than the alternative measure based on CPI all items less shelter.

Exhibit A-2

Quartile Distribution of Renter Households by Income and Rent, Under Inflation-adjusted Constant Quartile Breaks Based on CPI All Items and CPI All Items Less Shelter, 2016, United States (unit: percentage share)

	(a) CPI All Items		(b) CPI Less Shelter	
	Renter Income	Gross Rent	Renter Income	Gross Rent
Q4 (highest)	26	39	27	41
Q3	23	24	23	24
Q2	25	20	25	19
Q1 (lowest)	26	17	25	16

Notes: CPI = Consumer Price Index; this exhibit is a tabular display of constant quartile mismatch results that were graphically displayed as column graphs in exhibits 6 and 7.
Sources: 2000 Decennial Census and 2016 American Community Survey IPUMS Microdata files (Ruggles et al., 2018).

Choice of Base Year

Constant quartile mismatch measure gauges the 2016 level of rental affordability compared with the 2000 level because 2000 was the last year before boom, bust, and recovery periods. What if we use a different year as our base year instead of 2000?

Exhibit A-3 shows how constant quartile mismatch measure changes when we choose 2006 (panel b), peak of the housing market, as base year instead of 2000 (panel a). In terms of renter income, a 2006 base year results in a weaker shift of renters into higher end brackets compared with our original 2000 base year; for example, 26 percent in the top quartile based on 2000 base year (panel a) while 29 percent based on 2006 base year (panel b). That is understandable because renters' income actually declined between the alternative base years (2000 and 2006), which then lowered income quartile breaks ($ value) in 2006; consequently, a greater number of renters in 2016 were allocated into higher income brackets.

In contrast, rents increased the two base years (2000 and 2006) and the opposite happened to distribution of rental units. Based on the 2000 base year, 39 percent of rental units in 2016 were allocated to the top quartile (panel a). This is much higher than 32 percent in the top quartile based on a 2006 base year (panel b). In sum, the 2000 base year shows more serious affordability problems compared to a 2006 base year.

Exhibit A-3

Quartile Distribution of Renter Households in 2016, by Income and Rent, Based on Alternative 2000 and 2006 Base Years, Under Inflation-adjusted Constant Quartile Breaks, United States (unit: percentage share)

	(a) 2000 Base Yearr		(b) 2006 Base Year	
	Renter Income	**Gross Rent**	**Renter Income**	**Gross Rent**
Q4 (highest)	26	39	29	32
Q3	23	24	23	24
Q2	25	20	24	23
Q1 (lowest)	26	17	23	21

Note: This exhibit is a tabular display of constant quartile mismatch results that were graphically displayed as column graphs in exhibits 6 and 7.
Sources: 2000 Decennial Census and 2006 and 2016 American Community Survey IPUMS Microdata files (Ruggles et al., 2018).

Using the 2006 base year, when many more people became owners, remaining renters were left with lower incomes; whereas in 2016, the higher income renters are back, swelling the top quartile. The quartile based in 2006 therefore is set artificially low because of the bubble. That suggests keeping 2000 as the baseline because it precedes the volatility of boom, bust, and prolonged recovery.

Appendix B

Rent Burden and Constant Quartile Distribution of Renter Households, 2000 and 2016, United States and Largest 50 Metropolitan Areas, Ordered by 2016 Population (unit: percentage, percentage point changes) (1 of 3)

Rank by 2016 Pop	Metro Name	Rent Burden						Constant Quartile Distribution of Renter Households							
		(a) Total (30%+)			(b) Severe (50%+)			(c) By Renter Income				(d) By Gross Rent			
		2000	2016	2000 to 2016	2000	2016	2000 to 2016	Bottom Q1	Q2	Q3	Highest Q4	Bottom Q1	Q2	Q3	Highest Q4
	United States	38.0	47.5	9.5	19.6	25.2	5.6	25.7	25.4	23.1	25.9	17.1	19.7	24.0	39.1
1	New York	42.1	51.4	9.4	23.9	29.2	5.2	24.0	24.7	23.8	27.5	15.9	13.4	19.6	51.0
2	Los Angeles	45.5	57.3	11.9	23.8	31.8	8.0	24.5	23.2	23.0	29.3	11.0	14.2	20.3	54.4
3	Chicago	38.0	48.8	10.7	20.4	26.8	6.4	28.2	25.8	21.2	24.7	15.9	20.4	24.4	39.3
4	Dallas	34.4	44.6	10.1	15.9	21.0	5.2	28.5	23.5	22.6	25.4	15.1	22.2	24.6	38.2
5	Houston	35.2	47.0	11.9	17.9	24.9	7.0	27.4	24.7	21.7	26.3	12.2	17.7	24.7	45.4
6	Philadelphia	40.5	50.1	9.6	22.3	28.9	6.6	27.4	25.7	21.3	25.7	15.5	18.5	24.1	42.0
7	Washington, D.C.	34.0	46.1	12.1	15.9	24.0	8.1	26.5	19.3	23.0	31.1	11.4	10.6	20.0	58.1
8	Miami	47.9	61.2	13.3	26.1	34.0	8.0	22.2	26.7	24.8	26.4	11.2	15.4	21.9	51.6
9	Atlanta	37.8	46.7	8.9	17.7	23.5	5.7	30.4	24.6	22.5	22.6	21.5	25.9	21.7	30.9
10	Boston	38.3	47.3	9.0	19.7	25.4	5.7	26.9	23.1	21.7	28.3	19.8	14.1	18.2	47.9
11	SF-Oakland	40.0	45.6	5.7	19.8	23.7	3.9	24.0	19.1	23.3	33.6	15.7	12.9	22.8	48.6
12	Detroit	36.4	48.7	12.3	20.0	27.0	7.0	29.9	27.2	22.4	20.5	17.4	22.2	26.0	34.4
13	Riverside-SB	44.4	56.3	11.9	23.0	30.2	7.1	22.3	24.0	24.9	28.8	12.2	12.6	20.0	55.3
14	Phoenix	40.5	46.0	5.5	19.5	23.3	3.9	26.4	23.7	22.6	27.3	18.0	19.7	25.5	36.8
15	Seattle	39.1	45.9	6.7	18.2	22.0	3.7	23.9	20.7	22.3	33.2	13.6	14.8	19.6	51.9
16	Minneapolis	36.7	44.2	7.5	17.1	21.8	4.7	26.2	25.4	23.0	25.4	17.4	19.2	24.1	39.3
17	San Diego	43.3	55.0	11.8	20.9	29.1	8.1	23.3	20.4	23.7	32.6	9.0	12.8	20.0	58.2
18	St. Louis	35.3	43.5	8.3	18.7	21.8	3.1	23.2	28.4	24.2	24.3	14.1	20.6	26.5	38.8
19	Tampa	40.0	50.2	10.2	19.3	25.5	6.3	26.2	23.6	24.2	26.0	13.1	17.5	24.5	44.9
20	Baltimore	36.6	46.0	9.4	18.9	25.6	6.7	23.6	22.4	22.1	31.9	14.2	10.1	19.8	55.9

Appendix B

Rent Burden and Constant Quartile Distribution of Renter Households, 2000 and 2016, United States and Largest 50 Metropolitan Areas, Ordered by 2016 Population (unit: percentage, percentage point changes) (2 of 3)

Rank by 2016 Pop	Metro Name	Rent Burden						Constant Quartile Distribution of Renter Households							
		(a) Total (30%+)			(b) Severe (50%+)			(c) By Renter Income				(d) By Gross Rent			
		2000	2016	2000 to 2016	2000	2016	2000 to 2016	Bottom Q1	Q2	Q3	Highest Q4	Bottom Q1	Q2	Q3	Highest Q4
21	Denver	38.9	49.9	11.0	18.4	24.5	6.2	24.0	22.0	25.2	28.8	11.2	14.9	22.2	51.7
22	Pittsburgh	36.2	40.9	4.7	18.8	21.6	2.9	22.9	25.5	26.9	24.7	15.9	19.6	25.8	38.7
23	Portland	39.3	48.9	9.6	18.9	25.1	6.3	25.1	24.2	23.4	27.3	15.3	12.7	23.5	48.6
24	San Antonio	35.7	45.7	10.0	17.4	22.5	5.1	23.9	24.5	25.4	26.2	13.0	15.8	24.1	47.2
25	Sacramento	42.1	51.7	9.7	21.4	29.2	7.8	27.5	23.6	21.1	27.8	13.5	16.3	22.8	47.4
26	Orlando	41.6	54.1	12.4	19.3	27.7	8.4	27.8	25.5	23.3	23.3	14.5	18.7	24.6	42.2
27	Cincinnati	35.8	44.0	8.2	18.3	22.5	4.2	27.3	26.2	21.6	24.9	18.1	22.2	26.0	33.7
28	Cleveland	38.6	46.4	7.8	20.8	27.0	6.2	30.7	24.4	22.3	22.7	22.9	24.7	25.0	27.4
29	Kansas City	33.2	42.7	9.5	16.2	20.2	4.0	28.6	26.2	19.5	25.6	17.3	22.5	24.9	35.3
30	Las Vegas	41.7	50.2	8.5	19.4	25.7	6.3	31.2	22.3	22.4	24.1	25.8	20.2	20.4	33.6
31	San Jose	38.4	46.2	7.8	17.9	22.9	5.0	28.9	17.7	21.6	31.8	17.0	13.7	20.2	49.1
32	Columbus	35.2	43.3	8.1	18.0	23.3	5.4	28.8	22.8	24.6	23.8	18.6	22.6	25.8	33.0
33	Charlotte	33.3	43.5	10.2	16.3	21.7	5.4	29.6	26.3	21.2	22.9	18.7	22.6	24.1	34.5
34	Indianapolis	34.1	46.4	12.3	16.3	25.4	9.1	30.4	26.4	21.9	21.4	17.7	23.8	26.5	32.0
35	Austin	40.5	47.1	6.6	21.0	22.6	1.7	21.4	23.9	27.8	26.9	12.3	17.6	27.6	42.6
36	Virginia Beach	38.2	49.7	11.5	17.9	24.5	6.6	24.0	22.1	23.4	30.6	9.5	12.3	23.3	54.9
37	Providence	36.9	46.5	9.7	19.2	23.8	4.6	25.8	24.8	22.4	27.0	18.1	12.8	26.3	42.8
38	Nashville	36.1	42.8	6.6	17.4	20.5	3.1	25.4	23.3	23.1	28.3	17.2	18.9	22.6	41.3
39	Milwaukee	35.7	46.6	10.9	18.0	26.4	8.3	32.5	27.2	18.5	21.7	18.8	24.0	28.7	28.5
40	Jacksonville	35.2	46.3	11.1	16.6	23.9	7.4	26.5	25.8	24.3	23.4	12.2	20.4	26.8	40.6

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Rank by 2016 Pop	Metro Name	Rent Burden						Constant Quartile Distribution of Renter Households							
		(a) Total (30%+)			(b) Severe (50%+)			(c) By Renter Income				(d) By Gross Rent			
		2000	2016	2000 to 2016	2000	2016	2000 to 2016	Bottom Q1	Q2	Q3	Highest Q4	Bottom Q1	Q2	Q3	Highest Q4
41	Memphis	39.7	51.8	12.1	21.8	29.9	8.1	27.0	26.9	22.8	23.4	11.8	19.0	28.0	41.2
42	Louisville	33.5	43.2	9.7	17.3	20.6	3.3	25.7	29.3	23.1	21.9	18.7	16.1	28.0	37.2
43	Richmond	36.6	50.1	13.4	17.8	28.1	10.3	29.2	23.3	21.1	26.4	13.9	14.9	27.9	43.4
44	Oklahoma City	36.4	42.8	6.4	19.4	20.9	1.5	20.9	27.5	24.8	26.7	15.5	17.4	25.2	41.8
45	Hartford	36.0	48.7	12.7	18.8	27.3	8.5	31.2	25.0	23.3	20.6	18.2	17.0	23.7	41.1
46	New Orleans	42.5	55.9	13.5	24.3	31.2	6.9	23.0	28.0	23.1	25.8	12.5	11.6	24.1	51.8
47	Raleigh	36.8	38.2	1.4	18.2	17.8	-0.4	24.3	24.2	24.2	27.3	21.3	22.6	25.0	31.0
48	Buffalo	43.9	45.5	1.6	24.2	25.7	1.6	27.3	20.6	25.6	26.5	22.6	22.9	24.4	30.0
49	Salt Lake City	37.2	42.2	5.0	17.7	20.8	3.1	25.7	23.3	21.7	29.4	18.4	19.1	20.4	42.1
50	Birmingham	36.6	42.4	5.8	19.9	21.7	1.8	24.0	26.9	23.5	25.6	17.2	16.8	26.0	40.0
50 Metro Average		38.2	47.5	9.3	19.3	24.9	5.6	26.3	24.3	23.0	26.4	15.8	17.8	23.8	42.5
Standard Deviation		3.4	4.5	2.8	2.4	3.5	2.3	2.8	2.5	1.7	3.2	3.6	4.1	2.7	8.2

*Notes: * "Increase" is calculated as the quartile share in 2016 less the initial 25 percent share in 2000. ** "Combined" is calculated as top quartile difference minus bottom quartile difference. AMI = area median income. SF = San Francisco. Percentages may not match due to rounding at the first decimal place. For the purpose of comparison, we calculated indicators of affordable supply gap and availability of low-cost rentals with a focus on very low-income renter households (less than 50 percent of AMI) because they are the primary target population of major federal rental assistance programs. Household and housing unit size adjustments and physical adequacy of units were omitted in calculating indicators of affordable supply gap and availability both for simplicity and to maintain comparability with constant quartile mismatch and rent burden indicators. Shelter poverty indicator was not included in this comparison because of the complexity of its calculation, as previously discussed in exhibit 3.*

Sources: 2000 Decennial Census and 2016 American Community Survey IPUMS Microdata files (Ruggles et al., 2018).

Appendix C. Data and Sample Description

Data

We used the U.S. decennial census 5 percent Public Use Microdata Sample (PUMS) in 2000 from the Integrated Public Use Microdata Series (IPUMS) provided by the Minnesota Population Center (Ruggles et al., 2018). We also retrieved the American Community Survey (ACS) 1 percent Microdata Samples in 2006 through 2016 from the same source.

The primary analysis relies on certain advantages of the Microdata Samples over summary tables that are tabulated and provided by the U.S. Census Bureau through the American FactFinder website. First, the Microdata Samples specify all the detailed demographic and housing data required for the study. The aggregated format of summary tables does not allow us to follow our constant quartile mismatch approach. Second, a metropolitan identifier within microdata permits us to take advantage of consistent and comparable geographic definitions in the 2000 census and multiple ACS years for our constant quartile mismatch analysis. The geographic identifier will be explained in more detail.

A certain limitation to the use of the Microdata Samples should be noted. The smaller the geographic area, the greater the deviation that may occur between the ACS summary table and the result of tabulations from microdata samples. That is the result of the greater sampling error in the public use microdata than that of the data files the Census Bureau uses to produce their summary tables. As an accuracy check on our microdata-based household count, we compared microdata estimates of all renter-occupant households with corresponding American FactFinder's summary tables in the 2000 census and multiyear ACSs. Trends in the two indicators tracked very closely in both the nation as a whole and across the 50 largest metropolitan areas.

Sample

The study is an aggregate-level analysis of metropolitan areas, rather than an individual-household-level analysis. We focus on a sample of the 50 most populous metropolitan areas in 2016 so that we might prevent potential noise from small- and mid-sized areas in measuring rental affordability. According to 2016 ACS data, 177 million people (54.9 percent of the total U.S. population) and 64 million households (54.0 percent of the total U.S. households) lived in those areas in 2016. Simplified names of the largest 50 metropolitan areas were previously listed in appendix B. A metropolitan area is a region consisting of a large urban core together with surrounding communities that have a high degree of economic and social integration with the urban core.

Boundaries for the 50 metropolitan areas are specified in accordance with the geographical definitions used in the 2010 census. The IPUMS database provides a geographic variable, labeled MET2013, which identifies time-invariant and comparable areas of residence using 2013 definitions for metropolitan statistical areas (MSAs) from the U.S. Office of Management and Budget (OMB). The 2013 MSAs are the first to be based on 2010 standards and 2010 census data. Data from the 2000 census and the ACS in 2006 and later were rearranged by the Minnesota Population Center to conform to those 2013 definitions. The 2013 delineations used by MET2013 are entirely county-based, even in New England. The MET2013 variable is available for 2000 and

later years. Use of MET2013 is essential to identify both gross rent of an individual rental unit and income of its current occupant in each metropolitan area.

Quartile Affordability Calculation

This study estimates quartile rental affordability in the nation as a whole and in the 50 largest metropolitan areas. Elaborating on explanation in the text, to compute quartile affordability of metropolitan area *i* in year *j*, we begin by computing three quartile breaks of renter household income in metropolitan area *i* in 2000. By definition, the resulting dollar values split evenly all renter households in metro *i* in 2000 into four 25-percent brackets, summing to 100 percent. Next we adjust those dollar values to year *j* dollar values by adjusting for inflation. Then we count the number of renter households in metro *i* in year *j* that fall inside those updated brackets. Also computed is what share of all renter households in metro *i* in year *j* makes up each updated bracket. Note that the resulting distribution may or may not be split evenly into four 25-percent brackets depending on how the distribution falling into each bracket has expanded or shrunk since 2000. If current year j breaks were applied instead of the updated 2000 breaks, it should result in four even 25-percent brackets in year *j* by definition. At this stage, we can compute how much the share falling into each quartile defined in 2000 has changed by year *j*.

The same logic is applied to gross rents in place of renter household income. We compute three quartile breaks of gross rents in metropolitan area *i* in 2000, and then adjust those dollar values to year *j* dollar values by adjusting for inflation. Based on the updated 2000 brackets, we can count the number and share of renter households in metro *i* in year *j* that fall into those updated brackets. Now we can see that what was distributed evenly inside four 25-percent brackets of rents in metro *i* in 2000 has grown increasingly skewed by year *j*. Using those updated distributions of income and rents, we can represent how rental affordability in metro *i* has changed from 2000 to year *j*. For each metropolitan area *i*, we calculate the updated quartile distribution of income and rents, to make a comparison between metropolitan areas.