# Estimating the Price of Rents in Regional Price Parities

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## Abstract

In May of 2011, BEA published prototype estimates of 5-year regional price parities for states and metropolitan areas for 16 expenditure classes, including rents, for the 2005-2009 period. In previous research (*see:* Aten & Reinsdorf [2010], Aten & Heston [2009]), differences in interarea price comparisons were evaluated using various methods of constructing the multilateral indexes. In this paper we explore some of these results with respect to different treatments of shelter costs (rents), using data from both the Consumer Price Index and the American Community Survey.

## Overview of Regional Price Parities

Price indexes are commonly used to measure price level differences between one time period and the next, such as the consumer price index (CPI), published by the Bureau of Labor Statistics (BLS). The percent change in the CPI is a measure of inflation (or deflation). Regional Price Parities (RPPs) are price indexes that measure the price level differences between one place and another for one time period. The methodology and sampling requirements for the two techniques have important differences, which are detailed in *Regional Price Parities by Expenditure Class for 2005-2009* in the May 2011 issue of the Survey of Current Business.

The BEA first estimated regional price parities for 38 urban areas of the U.S. for 2003 and 2004 (*see:* Aten[2005, 2006]). The method was subsequently expanded to cover the remaining nonmetropolitan portions of each state, as well as for all fifty states plus the District of Columbia (hence referred to simply as "states"), and 366 metropolitan areas as defined by the Office of Management and Budget (OMB). These estimates incorporate recent five-year American Community Survey (ACS) data from the Census Bureau that includes coverage of rural areas, along with updated expenditure data reflecting regional distribution of rural cost weights.

For more details regarding the data and methodology used to estimate the RPPs, refer to the May 2011 Survey of Current Business (http://www.bea.gov/scb/toc/0511cont.htm).

## Rents and Quality-Adjusted Rent Estimates

With shelter costs comprising the largest share of expenditures in the Consumer Expenditure Survey (CE), we are particularly interested in the sensitivity of the RPPs given changes to the price-level estimates in this expenditure category, since they will have the largest impact on the overall RPPs. In a previous paper (*see:* Aten, Figueroa, and Martin [2011]), we compared RPPs estimated with rent prices using both BLS and ACS data, using separate models to estimate the mean area prices for each data set. One caveat in making such comparisons of the RPP rent estimates is that differences in the two survey designs make it difficult to compare rent at the same level of geography. The BLS samples annual rent prices for Primary Sampling Units (PSUs), including 31 metropolitan, 4 'small metropolitan', and 3 'urban, nonmetropolitan' sample areas[1] (hence referred to as "index areas"), representing about 87% of the total U.S. population. The ACS is designed as a snapshot of the total population over a 5-year period and covers all urban and rural U.S. counties, but uses OMB definitions for 366 metropolitan[2] areas, 574 micropolitan areas, and 1,355 rural counties. It is therefore possible to aggregate data from counties in the ACS into the 38 BLS areas in order to compare the results of both surveys; however due to the different sampling methodologies and survey design, we should not be surprised to observe some differences. The annual BLS data for 2005-2009 are combined in order to conduct a comparison with the ACS for the same period. Table 1 shows the average rent prices for the 38 BLS areas using both data sources.

[1] See: BLS Handbook of Methods, Chapter 17, http://www.bls.gov/opub/hom/pdf/homch17.pdf. "Small metropolitan" areas comprise the Northeast, Midwest, South and West Bs and the "non-metropolitan urban areas" refer to the Midwest, South and West Cs.

[2] OMB defines a Metropolitan Statistical Area as having at least one core urbanized area, with a population of 50,000 or more, along with its surrounding areas having a high degree of social and economic integration with the core. See: OMB Bulletin 09-01, http://www.census.gov/population/www/metroareas/metrodef.html

## Table 1 – Geometric Mean Rent Prices by BLS Primary Sampling Unit Areas, 2005-2009

| BLS Index Area | | Geometric Mean Rents (Normalized) | | Geometric Mean Rents (Dollars) | |
|---|---|---|---|---|---|
| **Area Code** | Area | ACS | BLS | ACS | BLS |
| **A102** | Philadelphia-Wilmington-Atlantic City, PA-NJ-DE-MD | 100.5 | 120.2 | 838 | 947 |
| **A103** | Boston-Brockton-Nashua, MA-NH-ME-CT | 108.2 | 144.0 | 902 | 1,135 |
| **A104** | Pittsburgh, PA | 71.8 | 71.7 | 599 | 565 |
| **A109** | New York City | 114.3 | 164.6 | 953 | 1,298 |
| **A110** | New York-Connecticut Suburbs | 127.7 | 137.4 | 1,065 | 1,083 |
| **A111** | New Jersey-Pennsylvania Suburbs | 120.6 | 136.4 | 1,005 | 1,075 |
| **A207** | Chicago-Gary-Kenosha, IL-IN-WI | 101.5 | 111.1 | 846 | 876 |
| **A208** | Detroit-Ann Arbor-Flint, MI | 87.9 | 87.2 | 733 | 687 |
| **A209** | St. Louis, MO-IL | 82.3 | 72.8 | 686 | 574 |
| **A210** | Cleveland-Akron, OH | 77.5 | 75.0 | 646 | 591 |
| **A211** | Minneapolis-St. Paul, MN-WI | 94.4 | 97.9 | 787 | 772 |
| **A212** | Milwaukee-Racine, WI | 87.4 | 82.7 | 729 | 652 |
| **A213** | Cincinnati-Hamilton, OH-KY-IN | 77.5 | 80.3 | 646 | 633 |
| **A214** | Kansas City, MO-KS | 86.4 | 76.9 | 720 | 607 |
| **A312** | Washington, DC-MD-VA-WV | 135.3 | 137.9 | 1,128 | 1,087 |
| **A313** | Baltimore, MD | 106.2 | 108.1 | 885 | 852 |
| **A316** | Dallas-Fort Worth, TX | 98.5 | 83.0 | 821 | 654 |
| **A318** | Houston-Galveston-Brazoria, TX | 96.9 | 78.2 | 808 | 616 |
| **A319** | Atlanta, GA | 105.0 | 90.4 | 876 | 713 |
| **A320** | Miami-Fort Lauderdale, FL | 115.3 | 110.0 | 961 | 867 |
| **A321** | Tampa-St. Petersburg-Clearwater, FL | 105.0 | 93.3 | 875 | 735 |
| **A419** | Los Angeles-Long Beach, CA | 125.9 | 140.0 | 1,049 | 1,104 |
| **A420** | Los Angeles Suburbs, CA | 143.2 | 140.2 | 1,194 | 1,105 |
| **A422** | San Francisco-Oakland-San Jose, CA | 143.8 | 165.0 | 1,199 | 1,301 |
| **A423** | Seattle-Tacoma-Bremerton, WA | 109.4 | 103.9 | 912 | 819 |
| **A424** | San Diego, CA | 141.2 | 143.7 | 1,177 | 1,133 |
| **A425** | Portland-Salem, OR-WA | 97.0 | 87.6 | 809 | 691 |
| **A426** | Honolulu, HI | 142.9 | 137.8 | 1,192 | 1,086 |
| **A427** | Anchorage, AK | 119.3 | 114.4 | 995 | 902 |
| **A429** | Phoenix-Mesa, AZ | 106.6 | 85.9 | 889 | 677 |
| **A433** | Denver-Boulder-Greeley, CO | 100.6 | 117.5 | 838 | 926 |
| **D200** | Midwest nonmetropolitan urban (MW Cs) | 63.3 | 62.0 | 527 | 489 |
| **D300** | South nonmetropolitan urban (South Cs) | 64.8 | 64.6 | 540 | 509 |
| **D400** | West nonmetropolitan urban (West Cs) | 83.4 | 87.7 | 695 | 691 |
| **X100** | Northeast small metropolitan (NE Bs) | 80.4 | 90.1 | 671 | 710 |
| **X200** | Midwest small metropolitan (MW Bs) | 77.1 | 74.3 | 643 | 586 |
| **X300** | South small metropolitan (South Bs) | 87.0 | 75.3 | 725 | 593 |
| **X499** | West small metropolitan (West Bs) | 101.1 | 92.4 | 843 | 728 |
| | Weighted Geometric Mean | 100.0 | 100.0 | 834 | 788 |
| | Maximum | 143.8 | 164.6 | 1199 | 1301 |
| | Minimum | 63.3 | 62.0 | 527 | 489 |
| | Range | 80.5 | 102.7 | 671 | 812 |

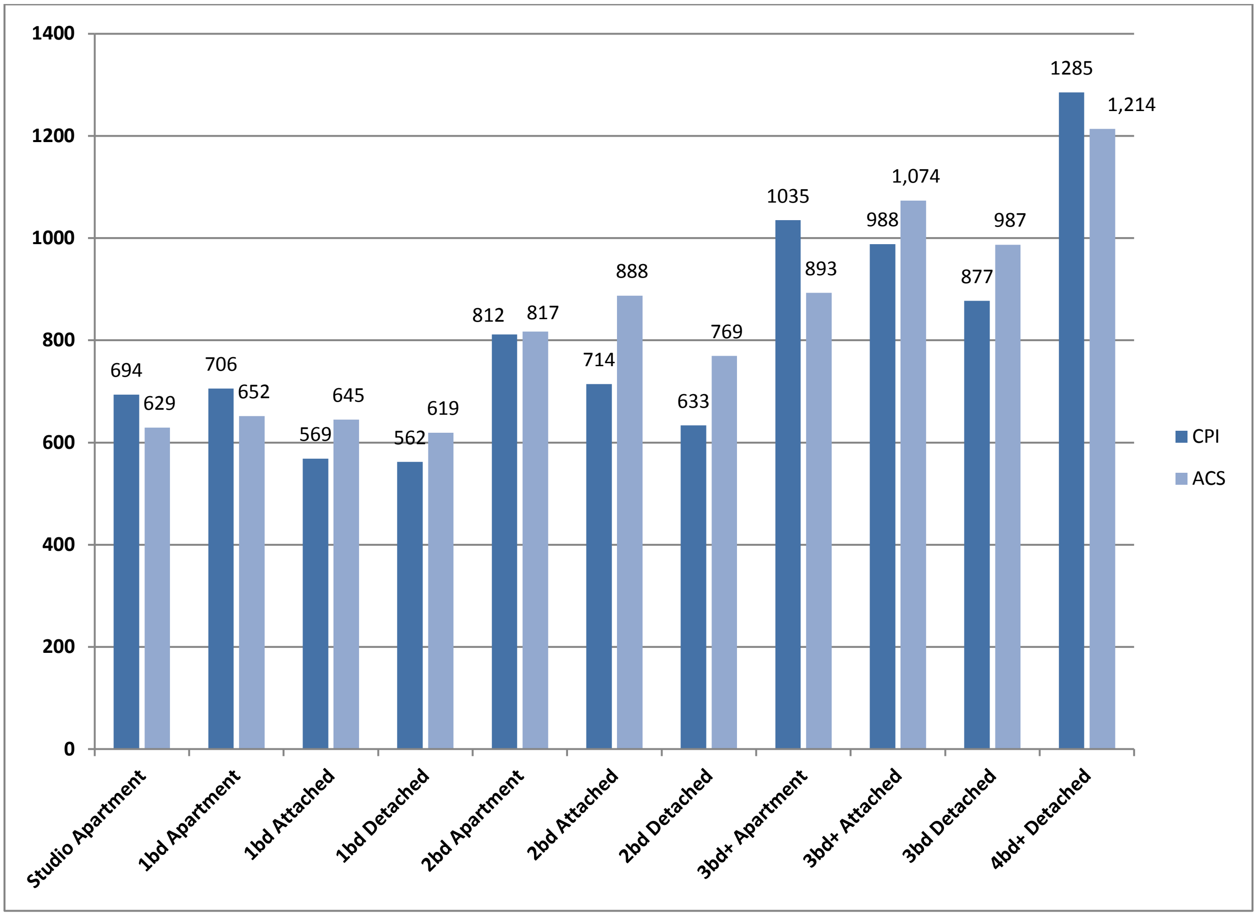
As we have seen in earlier research, the overall range of the normalized BLS rents is greater than in the ACS (103 vs. 80.5), and while some areas toward the middle of the distribution have similar averages in both data sets, the most expensive areas in the BLS survey tend to be much more so than in the ACS. For example, rents for New York City averaged $1,421 according to the BLS survey, but just $953 according to the ACS. And while Boston ranked as the third most expensive city in the BLS survey, it ranks as 13$^{th}$ in the ACS. Metro areas such as Atlanta, Tampa and Phoenix have above average rents (normalized price > 100.0) in the ACS but below average rents in the BLS survey. The Washington, D.C., Seattle, Cincinnati, Detroit, Portland and Pittsburgh index areas all yielded average rents that were very similar in both surveys.

Because both surveys collect data on not just the rents, but also the characteristics of the unit, it is desirable to do a quality adjustment in order to account for the unique attributes of each observation (also referred to as a hedonic adjustment or hedonic regression model). The greater number of recorded housing characteristics in the CPI allows us to include variables such as the number of bathrooms, the length of occupancy, and the availability and type of parking, but is a smaller sample (about 125,000 rental observations for the 2005-2009 period), whereas the ACS provides a more basic set of characteristics, but many more observations (over 8 million, roughly 2 million of which are rentals). Table 2 shows the unweighted sample counts of the rental units in both surveys, grouped into three types of dwelling – apartments, single family attached homes and single family detached homes – and by the number of bedrooms in the unit. Chart 1 shows the weighted geometric mean rents for the total U.S. as measured by both the BLS survey and the ACS.

**Table 2 – Unweighted Sample Counts of Rental Units in the BLS / ACS Surveys, 2005-2009**

| | | BLS | | ACS | |
|---|---|---|---|---|---|
| **Type of Dwelling** | **Number of Bedrooms** | **Frequency** | **Percent** | **Frequency** | **Percent** |
| **Apartments** | 0 | 2,548 | 2.1 | 69,968 | 3.4 |
| | 1 | 31,724 | 25.8 | 574,808 | 27.8 |
| | 2 | 36,022 | 29.3 | 594,084 | 28.8 |
| | 3+ | 7,815 | 6.4 | 148,595 | 7.2 |
| **Single Family Attached Homes** | 0 or 1 | 4,128 | 3.4 | 15,233 | 0.7 |
| | 2 | 12,100 | 9.9 | 60,143 | 2.9 |
| | 3+ | 4,977 | 4.1 | 54,268 | 2.6 |
| **Single Family Detached Homes** | 0 or 1 | 1,766 | 1.4 | 39,670 | 1.9 |
| | 2 | 7,780 | 6.3 | 164,174 | 8.0 |
| | 3 | 10,854 | 8.8 | 251,902 | 12.2 |
| | 4+ | 3,101 | 2.5 | 91,232 | 4.4 |
| **Total** | | **122,815** | **100.0** | **2,064,077** | **100.0** |

**Chart 1 – Weighted Geometric Mean Rents (Dollars), Total U.S., 2005-2009**




The unit / bedroom combinations in Table 2 and Chart 1 have been grouped according to the most common dwelling types appearing in both data sets. While both surveys observe apartments with more than 4 bedrooms, and single family detached homes with none, the relatively low count (and little differentiation in terms of rental price) of these cross-sections led us to group them into the 11 unit types appearing in Table 2. As a percentage share of the all units both surveys sample roughly equal numbers in each category, however the BLS survey samples a proportionally higher number of single family attached homes. Two bedroom attached units for example, comprise about 10 percent of the BLS sample but only 3 percent in the ACS.

There are several reasons why this grouping is appropriate pursuant to future RPP estimates and other research currently being conducted by the BEA. First, it allows us to do a more straightforward comparison of the average rents in both data sets for the most common types of rental units. Second, it allows us to produce robust quality-adjusted rents by the type of shelter and for the level of geography we are estimating: 38 index areas in the BLS survey, 51 States and 366 Metropolitan Statistical Areas (MSAs) in the ACS. Lastly, these eleven unit types serve as the basis of research currently underway by the BEA to update the imputation of

Owner-Occupied Rent Expenditures as a component of Personal Consumption Expenditures (PCE), and furthermore to produce PCE housing estimates at a sub-national level (see*: Can the American Community Survey be Used to Improve OOR Expenditures?* Aten [2011]).

For the 5-year RPP estimates published in the May 2011 Survey of Current business, we produced quality-adjusted rent estimates using both ACS and BLS data for the 38 BLS index areas, and ACS data for the states and MSAs[3]. These results were estimated using a series of hedonic regressions featuring a set of core dummy variables such as the region, age of the rental, number of bedrooms, number of total rooms and the type of the unit. Additional variables available in the BLS survey are also added such as whether parking is included with the rent, the number of bathrooms, and the length of tenant occupancy. The data are regressed against the log of the rents. Further research in housing model specification with these data sets has been done extensively by Aten (2005). In the following sections, we will compare the models used to produce our 2005-2009 RPPs with an updated model consistent with the 11 unit types listed in Table 2.

## Results of 2005-2009 Quality Adjusted Rents

Appendix Table 1 shows the 5-year results of the weighted log-linear rent regressions using the BLS housing survey and the ACS. Some of the differences in the surveys are apparent in comparing the parameters: Dallas, Houston, Atlanta and Phoenix are below the baseline (the West Bs) in the BLS survey, but above in the ACS; this is also true of the Northeast Bs, (however the result is less significant in the BLS survey). Houston in particular appears to have relative rents that differ to a significant degree between the surveys. While it is around 12 percent[4] below the West Bs in the BLS survey and closer to other areas such as Cincinnati and the West Cs, in the ACS it is 2 percent above the baseline and more on par with Dallas and Atlanta. This may be in part due to differences in the sampling methods and model specification, but could perhaps be due to a higher degree of rental market variability following the influx of residents to Houston after Hurricane Katrina in 2005; we might expect the broader sample of the ACS to perhaps provide a better snapshot for that period.

In the BLS data, the coefficient on “Apartments with elevator” is much higher (0.405) than it is for single family homes (0.067 for detached and 0.096 for attached), although the latter are not significantly different from zero. Even when we combine the “Mobile homes” and “Other” categories the coefficients on the Apartments with elevators remain high. This is not the case in the ACS data where they conform more closely with our expectation that the highest rent premiums are for detached single family homes, followed by attached single family homes, large

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[3] We also estimated rent RPPs for three combined metropolitan, micropolitan, and rural regions.

[4] The percentage impact of a dummy variable is interpreted as $100 * (e^{\hat{\beta}} - 1)$, where $\hat{\beta}$ is the value of the parameter estimate. *See*: Halvorsen and Palmquist (1984).

apartment buildings (greater than 10 units), smaller apartment buildings (less than 10 units), and Mobile and other residences.

The "Year built" variable captures more detail about relative rent differences in the ACS survey. The ACS codes the age of the structure for each decade back to 1940, for 1939 and earlier, for the 2000 - 2004 period and for 2005 and later. The BLS survey records whether the unit was built after or before 1990. In the BLS survey, structures built after 1990 have 14 percent higher rents than those built prior to 1990, while in the ACS we can observe that structures built more recently have much higher rent premiums (28 and 25 percent for the post-2005 and 2000-2004 periods) versus the baseline of 1939 and earlier.

The "number of bedrooms" variable coefficients are consistent in both data sets, as is the "total number of rooms". In the ACS, rents are increasing in the total number of rooms but at a decreasing rate beyond four total rooms. The same result was found using the BLS survey when adding the square of total rooms to the model. Appendix Table 1 however shows the simplest specification per each data set and not each of the subsequent models we have tested.

The "Survey year" parameters are also consistent across both data sets, with a larger variation in the BLS survey – approximately 10 percent less in 2005 relative to 2009, while the ACS shows around a 3 percent relative difference.

Parking amenities do not enter into the model as a significant coefficient in the BLS data, but the total bathrooms and length of occupancy do. Unfortunately, these characteristics do not appear in the ACS. However, the ACS does contain more precise location characteristics, such as whether the unit is in a rural or urban portion of the county, and this parameter value is also significant, where rural units are estimated to have an 8 percent lower relative rent premium versus urban units.

Although the overall RMSE is lower and the fit of the BLS model is better, the standard errors on the parameters themselves are generally much higher in the BLS data as the ACS has the much larger number of observations (2 million versus about 120,000 in the BLS survey for the 5-year period). Because our interest in running the hedonic regressions is to get the best possible measurements on the area-coefficients, obtaining the best-fitting model is not our primary concern (though we do want to make the best fit provided each data source). Doing a quality-adjustment on the rents given that we have such additional information about the unit characteristics makes sense; however, we have also experimented with taking the simple geometric mean of the rent observations, which results in generally very similar overall RPPs (*see*: Aten, Reinsdorf [2010]).

The hedonic models used to produce quality-adjusted rent means per area for the 2005-2009 RPPs take the form of Equation 1.

**Equation 1**

$$\ln P_{ij} = \sum_{i=1}^{M} \alpha_i A_{ij} + \sum_{n=1}^{N} \sum_{j=1}^{J(n)} \beta_j^n Z_{ij}^n + \varepsilon_{ij}$$

$A_{ij}$ is a set of area dummies
*Zij* is the set of unit characteristics with

*i = 1, …, M* geographic areas

*j = 1, …, J(n)* classifications

*n = 1, …, N* characteristics

For each set of *j* classifications, one $\beta_{jn}$ is equal to zero so that the equation is not overidentified.

A description of the included characteristics per each survey follows in Table 3.

**Table 3 -- Description of Inputs to Housing Model by Survey**

| ACS | |
|---|---|
| **Characteristics (n):** | **Classifications (j)** |
| **Geographic Areas:** | Level of geography being estimated:<br>• Index area (38 Urban areas)<br>• States (50 plus the District of Columbia)<br>• MSAs (366 metro areas) |
| **Number of Beds:** | 0, 1, 2, 3, 4, 5 or more |
| **Type of Structure:** | • Apartment building with 9 or fewer units<br>• Apartment building with 10 or more units<br>• Single Family Attached Home<br>• Single Family Detached Home<br>• Mobile home, trailer, Boat, Van or RV |
| **Total Rooms:** | 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 or more |
| **Survey Year:** | 2005, 2006, 2007, 2008, 2009 |
| **Year Built:** | • Before 1939<br>• 1940 - 1949<br>• 1950 - 1959<br>• 1960 - 1969<br>• 1970 - 1979<br>• 1980 - 1989<br>• 1990 - 1999<br>• 2000 - 2004<br>• After 2005 |

| BLS | |
|---|---|
| **Characteristics (n):** | **Classifications (j)** |
| **Geographic Areas:** | Index area (38 urban areas) |
| **Number of Beds:** | 0, 1, 2, 3, 4 or more |
| **Type of Structure:** | • Apartment building with elevator<br>• Apartment building without elevator<br>• Mobile home or RV<br>• Single family attached home<br>• Single family detached home<br>• Other |
| **Total Rooms:** | (numeric) |
| **Survey Year:** | 2005, 2006, 2007, 2008, 2009 |
| **Year Built:** | Before 1990, After 1990, or Unknown |
| **Number of Baths:** | (numeric) |
| **Length of Occupancy:** | (months) |

Once we have quality-adjusted mean rents by the type of area, we can compare the differences in the estimates of the two surveys, both in terms of the normalized price estimates and the overall RPPs resulting from the use of either data. Table 4 shows the normalized quality-adjusted rents using the ACS and BLS data.

## Table 4 – Quality Adjusted Rent Prices and Overall RPPs by BLS Primary Sampling Unit Areas

**2005-2009**

| BLS Index Area | | Quality-Adjusted Normalized Rent Prices | |
|---|---|---|---|
| Area Code | Area | ACS | BLS |
| A102 | Philadelphia-Wilmington-Atlantic City, PA-NJ-DE-MD | 104.1 | 110.9 |
| A103 | Boston-Brockton-Nashua, MA-NH-ME-CT | 115.3 | 143.9 |
| A104 | Pittsburgh, PA | 73.7 | 72.4 |
| A109 | New York City | 131.2 | 161.7 |
| A110 | New York-Connecticut Suburbs | 134.5 | 141.7 |
| A111 | New Jersey-Pennsylvania Suburbs | 130.3 | 143.9 |
| A207 | Chicago-Gary-Kenosha, IL-IN-WI | 106.0 | 112.2 |
| A208 | Detroit-Ann Arbor-Flint, MI | 86.9 | 85.9 |
| A209 | St. Louis, MO-IL | 82.9 | 78.0 |
| A210 | Cleveland-Akron, OH | 77.6 | 74.8 |
| A211 | Minneapolis-St. Paul, MN-WI | 98.7 | 95.7 |
| A212 | Milwaukee-Racine, WI | 90.0 | 83.9 |
| A213 | Cincinnati-Hamilton, OH-KY-IN | 78.6 | 80.7 |
| A214 | Kansas City, MO-KS | 83.3 | 76.7 |
| A312 | Washington, DC-MD-VA-WV | 135.8 | 131.2 |
| A313 | Baltimore, MD | 105.1 | 107.8 |
| A316 | Dallas-Fort Worth, TX | 96.6 | 83.8 |
| A318 | Houston-Galveston-Brazoria, TX | 96.0 | 80.9 |
| A319 | Atlanta, GA | 96.1 | 84.7 |
| A320 | Miami-Fort Lauderdale, FL | 117.3 | 107.0 |
| A321 | Tampa-St. Petersburg-Clearwater, FL | 100.2 | 93.7 |
| A419 | Los Angeles-Long Beach, CA | 137.1 | 147.2 |
| A420 | Los Angeles Suburbs, CA | 136.4 | 138.2 |
| A422 | San Francisco-Oakland-San Jose, CA | 150.2 | 166.7 |
| A423 | Seattle-Tacoma-Bremerton, WA | 108.3 | 103.9 |
| A424 | San Diego, CA | 140.4 | 141.1 |
| A425 | Portland-Salem, OR-WA | 93.4 | 90.0 |
| A426 | Honolulu, HI | 143.8 | 143.4 |
| A427 | Anchorage, AK | 117.9 | 122.5 |
| A429 | Phoenix-Mesa, AZ | 97.8 | 86.2 |
| A433 | Denver-Boulder-Greeley, CO | 98.8 | 109.8 |
| D200 | Midwest nonmetropolitan urban | 62.4 | 66.8 |
| D300 | South nonmetropolitan urban | 62.0 | 60.4 |
| D400 | West nonmetropolitan urban | 78.6 | 80.5 |
| X100 | Northeast small metropolitan | 83.0 | 91.8 |
| X200 | Midwest small metropolitan | 75.7 | 76.4 |
| X300 | South small metropolitan | 81.3 | 74.5 |
| X499 | West small metropolitan | 94.1 | 91.3 |
| | Weighted Geometric Mean | 100.0 | 100.0 |
| | Maximum | 150.2 | 166.7 |
| | Minimum | 62.0 | 60.4 |
| | Range | 88.2 | 106.3 |

After the quality adjustment, the within-area differences of the estimates become in general closer to each other.   The adjusted normalized rents in New York City (131.2 versus 161.7) are, for example, much closer together than the unadjusted normalized means in Table 1 (114.3 vs. 164.6).  This is also true for other relatively high-rent areas such as Boston, Philadelphia, San Diego and Seattle, but not for Milwaukee or Los Angeles.  Overall however, the within-area differences are lower with the quality adjustment.  In addition, none of the adjusted area rent estimates were above the mean in one survey but below the mean in the other, with the exception of Denver (98.8 vs. 109.8) and Tampa (100.2 vs. 93.7.

Due to data constraints, we are not able to construct state or MSA-level estimates using the BLS housing survey to make a similar comparison with the ACS.  However, in attempting to measure the rents for BLS sampling units with the ACS, we are primarily interested in testing the sensitivity of the overall price-level estimates with respect to the two data sets.  The RPPs as estimated by either set of housing data tend to remain close, both in rank and distance from the overall “national” price level.  The trade-off of fewer recorded housing characteristics (such as no variable for the number of bathrooms) in the ACS for a much larger sample that includes rural coverage does not compromise the ability to generate robust RPP estimates for a broader set of geographies, including the states and 366 metro areas.

## Alternative Model Estimation using the ACS and Type / Structure Interaction

One question that arises when considering the appropriate model specification for quality-adjusted rent estimates is whether there is a structural difference in the parameter estimates by the type of building being estimated.  An extra bedroom in an apartment building might be expected to have a different rent premium than that of a single family detached home; this might also be true of the age of the building.  In this section we will consider an unrestricted model which allows the coefficients to vary based on the type of structure, following the 11 unit types that appear in Chart 1.  We exclude mobile units and other types of structures (such as boats) and treat apartment buildings as one category. If it is true that a structural difference exists, then adjusting the model would not only improve the quality-adjusted rent estimates but potentially enable us to estimate quality-adjusted rent means by the type of structure, for the specific type of unit/bedroom combination for each area.

Using the ACS data, we ran several models in order to compare the results of the parameter estimates: one over all areas, one adding area dummies for the states, and finally one model with 366 MSA dummies.  The results for the regression over all areas and states appear in Appendix Tables 2 and 3.

Whether looking at the regression results without area dummies or with the states and MSAs added, the coefficients estimated by the separate regressions by structure type do appear to vary from the combined regression results. When area dummies for the states are added, the impact of an attached home being built in a rural versus urban area is about half that of all structures (-9.6 versus -18.5 percent).

The survey year parameter estimates between attached and detached structures track closely, with a large jump in the distance from the 2009 baseline relative to other years. This is of interest particularly with respect to the peak of the housing market occurring in early 2006. In the results of the ACS regressions for all areas, this peak appears to be reflected at least to some degree in the rents, where the coefficient on detached homes jumps from about 3.9 percent below the baseline in 2005 to about 1.7 percent below in 2006, remains roughly the same for 2007, and moves slightly closer at 1.6 percent below in 2008. These results are consistent when the state and metro area dummies are included (Appendix Table 3). The same trend is not apparent in the survey year coefficients in the BLS model, which shows a more constant year to year increase in rental prices over the five year period.

The impact of the building age on the level of rents also varies by structure type. The results for all areas show that rent for apartments tends to be less sensitive to the age of the building, with buildings constructed after 2005 around 17.8% higher than those built before the baseline of 1939. In comparison, rents of attached and detached single family homes built after 2005 are estimated to be 34.9 and 47 percent higher than those built before 1940[5] (Appendix Table 2).

The "total rooms" variable behaves similarly to Appendix Table 1 (with the 38 Index Areas for the regional dummies). The greater the number of rooms, the higher is the rent, but at a decreasing rate. One anomaly is the regression for apartments only, where the baseline "9 total rooms" is actually less expensive than any other number of total rooms. It is likely in this case that some of these observations should be grouped into "5 or more" or run as a continuous variable, as there are likely to be very few apartment units with seven, eight, nine, or more total rooms. Apartments also exhibit a much narrower difference across the total number of rooms (2.7 percent lower than the baseline for 1 total rooms, while detached homes were 41.2 percent lower), perhaps because the total number of rooms in apartments is likely to be closer to the number of bedrooms.

One way to measure the degree to which the data exhibits a structural difference by the type of building is by applying a Chow test. In other words, the Chow test can be used to ask whether

[5] There is a discrepancy in the 2005-2009 ACS dictionary with respect to the year-built (YBL) variable. While the code book lists definitions specific to 2005, 2006, 2007, 2008, and 2009, those individual categories appear not to be coded in the data. Instead they appear to follow the definitions of the 2007 ACS data dictionary. For our 2006-2010 estimates we hope to be able to make use of the more specific definitions for recent years when estimating the quality-adjusted rents.

subsets of the parameters for separate dwelling types are equal or not (*see*: Chow [1960]). An F-test is applied to the regression results using Equation 2, following Kennedy (2003):

**Equation 2**

$$\frac{[SSE(restricted) - SSE(unrestricted)]/K}{SSE(unrestricted)/(T - 2K)}$$

Where *K* is the number of parameters and *T* the number of observations, and *SSE* is the sum of squared residuals in the restricted and unrestricted models.

In the restricted regression – that is, the model that is not adjusted for the specific dwelling/bedroom combination – we regress against the number of bedrooms, plus the type of structure, plus the other characteristics we are controlling for. In the unrestricted regression we interact the type of structure with each of the other independent variables[6]. If the F-test rejects the null hypothesis that the parameter estimates in the constrained equation equal those of the unconstrained, then a structural difference is assumed to exist. Table 5 summarizes the results of the Chow test.

**Table 5 – Results of Chow Tests for Unrestricted Regressions**

| Model | SSE (R) | SSE (UR) | K | Obs | F | Pr > F |
|---|---|---|---|---|---|---|
| All Areas | 9,925,555 | 9,848,073 | 73 | 2,064,077 | 222.4 | <.0001 |
| States | 8,466,794 | 8,381,262 | 223 | 2,064,077 | 94.4 | <.0001 |
| MSAs | 6,715,719 | 6,649,367 | 1153 | 1,748,255 | 15.1 | <.0001 |

In all three tests, there is strong evidence that the parameter estimates vary significantly by the type of structure being estimated, as indicated by the F-statistic. Additionally, in considering the summary statistics of each regression, all three of the unrestricted models had a lower coefficient of variation, root-mean square error, and a higher coefficient of determination ($R^2$). The full results of the output for all areas and states appear in in Appendix Tables 2 and 3.

[6] In Appendix Tables 2 and 3, these are represented (and run) as separate regressions by each type of structure. The results of the Chow test compare one unrestricted model that interacts the structure type with every other independent variable. The results as they appear in Tables A2 and A3 are presented so that a more straightforward comparison of the coefficients is possible. In these tables, the unrestricted sum of square errors is the sum of the square errors of all three separate models. The CV, RMSE, and $R^2$ for the full unrestricted regression were 30.1769, 2.0152, and 0.2621, respectively. The full output of the unrestricted table is excluded for the sake of brevity.

## Conclusions and Future Research

In this paper we have reviewed our most recent approaches to estimating shelter costs in regional price parities. The availability of the 5-year ACS housing file has enabled us for the first time to produce observed rather than imputed rent estimates at the state and metropolitan area levels. Because the ACS includes full county-level coverage, we are also able to evaluate the robustness of the resulting RPP estimates using the housing data from either the ACS or BLS Housing Survey. When measuring the price levels using either survey the resulting RPPs are very close.

The BLS housing survey collects a wealth of information about its sampled units and is designed to represent the U.S. urban population, defined as 38 total urban areas. While the ACS collects rent and owner-cost data for a greater number of units, it does not survey the characteristics of the sampled households as extensively as does the BLS. However, in comparing the simple geometric mean rents with the quality-adjusted rent estimates for each region, and additionally in comparing the resulting RPPs from each method of housing cost measurement, we conclude that the ACS is also an excellent source of data to leverage in order to produce these rent estimates. Additionally, because ACS provides county-level coverage, it is better suited for estimating rents for the states and metropolitan areas.

In the future, we hope to make more extensive use of the ACS to produce better rent-specific RPPs at additional levels of geographic detail, such as for Micropolitan areas and counties. Since the BEA is simultaneously looking to update its methodology for imputation of owner-occupied rent expenditures in the PCE, this research will ideally be useful in helping to produce sub-national rent expenditure estimates along with our next series of RPPs for the 2006-2010 time period. Further updates to this research will become available at on the BEA website at http://www.bea.gov/papers/working_papers.htm.

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**Appendix Table 1 – Annual Regression Results of Rent Prices in the ACS and BLS Housing Survey**

| | ACS | | | | | BLS | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Estimate** | **Error** | **t** | **Pr > \|t\|** | **Parameter** | **Estimate** | **Error** | **t** | **Pr > \|t\|** |
| Intercept | 6.7611 | 0.0043 | 1585.2 | <.0001 | Intercept | 6.0996 | 0.0131 | 466.8 | <.0001 |
| **Area** | | | | | **Area** | | | | |
| Philadelphia | 0.1005 | 0.0028 | 36.5 | <.0001 | Philadelphia | 0.1980 | 0.0079 | 33.2 | <.0001 |
| Boston | 0.2032 | 0.0026 | 77.7 | <.0001 | Boston | 0.4531 | 0.0079 | 62.6 | <.0001 |
| Pittsburgh | -0.2443 | 0.0041 | -59.7 | <.0001 | Pittsburgh | -0.2309 | 0.0079 | -22.0 | <.0001 |
| NY city | 0.3322 | 0.0020 | 163.9 | <.0001 | NY city | 0.5684 | 0.0083 | 82.5 | <.0001 |
| NY sub | 0.3572 | 0.0030 | 120.5 | <.0001 | NY sub | 0.4384 | 0.0079 | 57.4 | <.0001 |
| NJ sub | 0.3256 | 0.0026 | 127.7 | <.0001 | NJ sub | 0.4537 | 0.0079 | 58.0 | <.0001 |
| Chicago | 0.1189 | 0.0024 | 50.6 | <.0001 | Chicago | 0.2054 | 0.0080 | 27.7 | <.0001 |
| Detroit | -0.0793 | 0.0030 | -26.4 | <.0001 | Detroit | -0.0617 | 0.0078 | -5.6 | <.0001 |
| St.Louis | -0.1264 | 0.0039 | -32.2 | <.0001 | St.Louis | -0.1588 | 0.0079 | -22.5 | <.0001 |
| Cleveland | -0.1933 | 0.0036 | -53.8 | <.0001 | Cleveland | -0.1992 | 0.0078 | -17.8 | <.0001 |
| Minneapolis | 0.0478 | 0.0037 | 12.9 | <.0001 | Minneapolis | 0.0428 | 0.0079 | 13.2 | <.0001 |
| Milwaukee | -0.0450 | 0.0043 | -10.6 | <.0001 | Milwaukee | -0.0842 | 0.0079 | -6.8 | <.0001 |
| Cincinnati | -0.1799 | 0.0042 | -42.4 | <.0001 | Cincinnati | -0.1231 | 0.0078 | -13.9 | <.0001 |
| Kansas City | -0.1217 | 0.0044 | -27.9 | <.0001 | Kansas City | -0.1741 | 0.0078 | -21.0 | <.0001 |
| DC | 0.3670 | 0.0028 | 132.9 | <.0001 | DC | 0.3601 | 0.0079 | 52.8 | <.0001 |
| Baltimore | 0.1106 | 0.0038 | 29.1 | <.0001 | Baltimore | 0.1636 | 0.0079 | 19.0 | <.0001 |
| Dallas | 0.0261 | 0.0026 | 10.1 | <.0001 | Dallas | -0.0855 | 0.0078 | -14.5 | <.0001 |
| Houston | 0.0202 | 0.0027 | 7.4 | <.0001 | Houston | -0.1226 | 0.0078 | -19.4 | <.0001 |
| Atlanta | 0.0209 | 0.0030 | 7.1 | <.0001 | Atlanta | -0.0747 | 0.0078 | -10.6 | <.0001 |
| Miami | 0.2201 | 0.0030 | 73.1 | <.0001 | Miami | 0.1544 | 0.0078 | 26.6 | <.0001 |
| Tampa | 0.0623 | 0.0037 | 16.8 | <.0001 | Tampa | 0.0303 | 0.0078 | 3.2 | 0.0015 |
| LA | 0.3766 | 0.0021 | 181.8 | <.0001 | LA | 0.4729 | 0.0078 | 62.0 | <.0001 |
| Greater LA | 0.3709 | 0.0025 | 146.4 | <.0001 | Greater LA | 0.4144 | 0.0078 | 53.0 | <.0001 |
| San Francisco | 0.4678 | 0.0024 | 198.7 | <.0001 | San Francisco | 0.6017 | 0.0078 | 78.6 | <.0001 |
| Seattle | 0.1401 | 0.0030 | 46.9 | <.0001 | Seattle | 0.1276 | 0.0079 | 19.9 | <.0001 |
| San Diego | 0.3999 | 0.0033 | 123.0 | <.0001 | San Diego | 0.4363 | 0.0078 | 56.5 | <.0001 |
| Portland | -0.0079 | 0.0036 | -2.2 | 0.0301 | Portland | -0.0107 | 0.0078 | 0.9 | 0.3717 |
| Honolulu | 0.4238 | 0.0058 | 73.6 | <.0001 | Honolulu | 0.4515 | 0.0078 | 62.2 | <.0001 |
| Anchorage | 0.2250 | 0.0101 | 22.2 | <.0001 | Anchorage | 0.2933 | 0.0078 | 36.9 | <.0001 |
| Phoenix | 0.0380 | 0.0032 | 11.8 | <.0001 | Phoenix | -0.0561 | 0.0078 | -10.7 | <.0001 |
| Denver | 0.0484 | 0.0035 | 13.8 | <.0001 | Denver | 0.1833 | 0.0078 | 27.8 | <.0001 |
| MW Cs | -0.4103 | 0.0021 | -193.9 | <.0001 | MW Cs | -0.3175 | 0.0078 | -39.4 | <.0001 |
| South Cs | -0.4171 | 0.0019 | -220.1 | <.0001 | South Cs | -0.4090 | 0.0078 | -51.0 | <.0001 |
| West Cs | -0.1804 | 0.0024 | -75.0 | <.0001 | West Cs | -0.1266 | 0.0079 | -14.5 | <.0001 |
| NE Bs | -0.1254 | 0.0020 | -64.1 | <.0001 | NE Bs | 0.0056 | 0.0079 | 3.4 | 0.0007 |
| MW Bs | -0.2182 | 0.0019 | -117.6 | <.0001 | MW Bs | -0.1797 | 0.0078 | -21.3 | <.0001 |
| South Bs | -0.1466 | 0.0016 | -94.2 | <.0001 | South Bs | -0.2031 | 0.0078 | -26.1 | <.0001 |
| West Bs | 0.0000 | . | . | . | West Bs | 0.0000 | . | . | . |

| | ACS | | | | | BLS | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Estimate** | **Error** | **t** | **Pr>\|t\|** | **Parameter** | **Estimate** | **Error** | **t** | **Pr>\|t\|** |
| **Type of Structure** | | | | | **Type of Structure** | | | | |
| Single Fam. Detached | 0.2981 | 0.0018 | 162.1 | <.0001 | Single Fam. Detached | 0.0668 | 0.0394 | 1.7 | 0.0904 |
| Single Fam. Attached | 0.2233 | 0.0022 | 101.0 | <.0001 | Single Fam. Attached | 0.0957 | 0.0394 | 2.4 | 0.0151 |
| Apartment (<= 9 units) | 0.1400 | 0.0018 | 76.8 | <.0001 | Mobile Home | -0.1784 | 0.0434 | -4.1 | <.0001 |
| Apartment (10+ units) | 0.1479 | 0.0019 | 79.0 | <.0001 | Apartment w. Elevator | 0.4051 | 0.0394 | 10.3 | <.0001 |
| Mobile / Other | 0.0000 | . | . | . | Apartment w.o. Elevator | 0.1110 | 0.0393 | 2.8 | 0.0048 |
| | | | | | Other | 0.0000 | . | . | . |
| **Year Built** | | | | | **Year Built** | | | | |
| After 2005 | 0.2777 | 0.0023 | 120.6 | <.0001 | After 1990 | 0.1414 | 0.0043 | 32.6 | <.0001 |
| 2000 – 2004 | 0.2518 | 0.0016 | 159.3 | <.0001 | Unknown | 0.0604 | 0.0131 | 4.6 | <.0001 |
| 1990 – 1999 | 0.1691 | 0.0014 | 123.6 | <.0001 | Before 1990 | 0.0000 | . | . | . |
| 1980 – 1989 | 0.0850 | 0.0013 | 66.4 | <.0001 | | | | | |
| 1970 – 1979 | 0.0190 | 0.0012 | 15.9 | <.0001 | | | | | |
| 1960 – 1969 | -0.0081 | 0.0013 | -6.3 | <.0001 | | | | | |
| 1950 – 1959 | -0.0314 | 0.0013 | -23.4 | <.0001 | | | | | |
| 1940 – 1949 | -0.0519 | 0.0016 | -33.3 | <.0001 | | | | | |
| Before 1939 | 0 | . | . | . | | | | | |
| **Bedrooms** | | | | | **Bedrooms** | | | | |
| 0 | -0.3328 | 0.0059 | -56.7 | <.0001 | 0 | -0.3327 | 0.0103 | -32.2 | <.0001 |
| 1 | -0.2502 | 0.0041 | -61.7 | <.0001 | 1 | -0.2691 | 0.0074 | -36.3 | <.0001 |
| 2 | -0.0437 | 0.0039 | -11.2 | <.0001 | 2 | -0.2243 | 0.0062 | -36.3 | <.0001 |
| 3 | 0.0209 | 0.0038 | 5.5 | <.0001 | 3 | -0.1767 | 0.0054 | -32.5 | <.0001 |
| 4 | 0.0628 | 0.0038 | 16.5 | <.0001 | 4 | 0.0000 | . | . | . |
| 5 | 0.0000 | . | . | . | | | | | |
| **Total Rooms** | | | | | **Total Rooms** | 0.0608 | 0.0013 | 48.0 | <.0001 |
| 1 | -0.2732 | 0.0059 | -46.6 | <.0001 | | | | | |
| 2 | -0.2724 | 0.0038 | -72.0 | <.0001 | | | | | |
| 3 | -0.2669 | 0.0036 | -75.2 | <.0001 | | | | | |
| 4 | -0.2371 | 0.0034 | -69.6 | <.0001 | | | | | |
| 5 | -0.1816 | 0.0033 | -54.6 | <.0001 | | | | | |
| 6 | -0.1118 | 0.0033 | -33.8 | <.0001 | | | | | |
| 7 | -0.0459 | 0.0034 | -13.4 | <.0001 | | | | | |
| 8 | 0.0076 | 0.0037 | 2.0 | 0.0432 | | | | | |
| 9 | 0.0000 | . | . | . | | | | | |
| **Survey Year** | | | | | **Survey Year** | | | | |
| 2005 | -0.0332 | 0.0011 | -31.6 | <.0001 | 2005 | -0.1033 | 0.0027 | -38.7 | <.0001 |
| 2006 | -0.0210 | 0.0010 | -20.2 | <.0001 | 2006 | -0.0706 | 0.0027 | -26.4 | <.0001 |
| 2007 | -0.0185 | 0.0010 | -17.9 | <.0001 | 2007 | -0.0371 | 0.0027 | -13.9 | <.0001 |
| 2008 | -0.0170 | 0.0010 | -16.6 | <.0001 | 2008 | -0.0086 | 0.0027 | -3.2 | 0.0013 |
| 2009 | 0.0000 | . | . | . | 2009 | 0.0000 | . | . | . |
| **Other** | | | | | **Other** | | | | |
| Rural | -0.0807 | 0.001 | -66.2 | <.0001 | Total Bathrooms | 0.1864 | 0.0029 | 65.3 | <.0001 |
| Urban | 0 | . | . | . | Parking Included | -0.0019 | 0.0026 | -0.7 | 0.4594 |
| | | | | | Parking not included | 0.0000 | . | . | . |
| | | | | | Length of Occupancy | -0.0007 | 0.0000 | -53.9 | <.0001 |
| Sum of Squares | 3,442,808 | | | | Sum of Squares | 23.6511 | | | |
| Sum of Square Errors | 7,996,995 | | | | Sum of Square Errors | 16.9057 | | | |
| RMSE | 1.938673 | | | | RMSE | 0.01164 | | | |
| $R^2$ | 0.3010 | | | | $R^2$ | 0.5832 | | | |
| CV | 29.0844 | | | | CV | 0.1747 | | | |
| Observations | 2,127,804 | | | | Observations | 124,830 | | | |

## Appendix Table 2 – Unconstrained and Constrained Regression Results, All Areas

| | Restricted | | Unrestricted | | | | | |
|---|---|---|---|---|---|---|---|---|
| | All Structure Types | | Apartments | | Attached Single Fam. | | Detached Single Fam. | |
| **Parameter[7]** | **Est.** | **t** | **Est.** | **t** | **Est.** | **t** | **Est.** | **t** |
| Intercept | 7.1694 | 2100.2 | 6.7333 | 1022.1 | 7.0639 | 582.9 | 7.1516 | 2044.3 |
| **Urban / Rural** | | | | | | | | |
| Rural | -0.3028 | -218.3 | -0.3296 | -142.8 | -0.1772 | -28.3 | -0.2877 | -187.1 |
| Urban | 0.0000 | . | 0.0000 | . | 0.0000 | . | 0.0000 | . |
| **Bedrooms** | | | | | | | | |
| 0 | -0.4640 | -85.3 | -0.2772 | -47.4 | - | - | - | - |
| 1 | -0.4623 | -158.3 | -0.2400 | -98.8 | -0.3405 | -44.5 | -0.4225 | -97.7 |
| 2 | -0.2575 | -98.4 | -0.0242 | -12.2 | -0.0956 | -23.5 | -0.2553 | -97.2 |
| 3 | -0.1664 | -71.3 | 0.0000 | . | 0.0000 | . | -0.1091 | -52.3 |
| 4 | 0.0000 | . | | - | - | - | 0.0000 | . |
| **Total Rooms** | | | | | | | | |
| 1 | -0.1918 | -31.6 | 0.0522 | 5.8 | -0.3443 | -12.7 | -0.3800 | -30.7 |
| 2 | -0.1455 | -37.0 | 0.0652 | 9.3 | -0.2871 | -16.8 | -0.3158 | -42.2 |
| 3 | -0.1643 | -44.8 | 0.0493 | 7.2 | -0.2846 | -20.9 | -0.2809 | -54.4 |
| 4 | -0.1611 | -46.1 | 0.0533 | 7.9 | -0.2792 | -22.6 | -0.2732 | -69.1 |
| 5 | -0.1172 | -34.6 | 0.1038 | 15.6 | -0.2211 | -18.5 | -0.2306 | -64.4 |
| 6 | -0.0581 | -17.2 | 0.1628 | 23.9 | -0.1531 | -12.8 | -0.1689 | -48.6 |
| 7 | -0.0069 | -1.9 | 0.1992 | 25.1 | -0.0760 | -6.0 | -0.1098 | -30.9 |
| 8 | 0.0295 | 7.2 | 0.1961 | 19.4 | -0.035* | -2.5 | -0.0557 | -14.1 |
| 9 | 0.0000 | . | 0.0000 | . | 0.0000 | . | 0.0000 | . |
| **Survey Year** | | | | | | | | |
| 2005 | -0.0383 | -31.8 | -0.0346 | -22.3 | -0.0464 | -10.1 | -0.0402 | -20.4 |
| 2006 | -0.0246 | -20.6 | -0.0254 | -16.5 | -0.0197 | -4.3 | -0.0175 | -9.0 |
| 2007 | -0.0213 | -17.9 | -0.0213 | -13.9 | -0.0190 | -4.2 | -0.0165 | -8.6 |
| 2008 | -0.0168 | -14.3 | -0.0170 | -11.2 | -0.0148 | -3.3 | -0.0158 | -8.3 |
| 2009 | 0.0000 | . | 0.0000 | . | 0.0000 | . | 0.0000 | . |
| **Year Built** | | | | | | | | |
| After 2005 | 0.2430 | 94.8 | 0.1645 | 48.8 | 0.2995 | 35.6 | 0.3852 | 93.1 |
| 2000 – 2004 | 0.2070 | 120.7 | 0.1385 | 63.7 | 0.2536 | 39.8 | 0.3278 | 108.5 |
| 1990 – 1999 | 0.1003 | 67.7 | 0.0269 | 14.4 | 0.1923 | 34.0 | 0.2142 | 81.8 |
| 1980 – 1989 | 0.0236 | 17.2 | -0.0584 | -33.8 | 0.1816 | 34.5 | 0.1730 | 69.5 |
| 1970 – 1979 | -0.0356 | -27.6 | -0.1156 | -70.6 | 0.1082 | 21.3 | 0.1096 | 49.6 |
| 1960 – 1969 | -0.0243 | -17.2 | -0.0830 | -45.2 | 0.0237 | 4.1 | 0.0736 | 32.8 |
| 1950 – 1959 | -0.0287 | -19.3 | -0.0769 | -37.2 | 0.012* | 2.3 | 0.0609 | 29.2 |
| 1940 – 1949 | -0.0426 | -24.5 | -0.0595 | -24.5 | -0.0385 | -6.1 | 0.0163 | 6.7 |
| Before 1939 | 0.0000 | . | 0.0000 | . | 0.0000 | . | 0.0000 | . |
| **Structure Type** | | | | | | | | |
| Apartments | -0.0588 | -51.9 | - | | - | | - | |
| Attached | 0.0295 | 16.6 | - | | - | | - | |
| Detached | 0.0000 | . | - | | - | | - | |
| **Sum of Squares** | 1,432,289 | | 612,263 | | 77,055 | | 474,810 | |
| **Sum of Square Errors** | 9,925,555 | | 7,326,782 | | 543,274 | | 1,706,739 | |
| **RMSE** | 2.1929 | | 2.3180 | | 2.0557 | | 1.7763 | |
| **$R^2$** | 0.1261 | | 0.0771 | | 0.1242 | | 0.2176 | |
| **CV** | 32.8380 | | 35.0573 | | 30.0827 | | 26.0191 | |
| **Observations** | 2,064,077 | | 1,363,642 | | 128,586 | | 540,925 | |

[7] All parameter estimates are significant at P < .0001 with the exception of cells marked "*" in the Attached Single Family Homes column. Those estimates are significant at P < .05.

## Appendix Table 3 – Restricted and Unrestricted Regression Results, States

| | Restricted | | Unrestricted | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **All Structure Types** | | Apartments | | Attached Single Fam. | | Detached Single Fam. | |
| **Parameter** | **Est.** | **t** | **Est.** | **t** | **Est.** | **t** | **Est.** | **t** |
| Intercept | 6.8928 | 709.0 | 6.3818 | 447.3 | 6.8554 | 181.94 | 6.9999 | 553.3 |
| **State** | | | | | | | | |
| Alabama | -0.0767 | -7.9 | -0.0500 | -3.7 | -0.0996 | -2.5 | -0.1168 | -9.0 |
| Alaska | 0.4082 | 34.3 | 0.4644 | 28.7 | 0.5141 | 12.1 | 0.3714 | 20.2 |
| Arizona | 0.2315 | 24.2 | 0.2818 | 21.1 | 0.1522 | 4.1 | 0.1702 | 13.3 |
| Arkansas | -0.1136 | -11.4 | -0.1151 | -8.2 | -0.0988 | -2.5 | -0.1342 | -10.3 |
| California | 0.5693 | 61.5 | 0.6416 | 49.5 | 0.5490 | 15.2 | 0.4628 | 37.4 |
| Colorado | 0.2425 | 25.2 | 0.2729 | 20.4 | 0.2260 | 6.1 | 0.2125 | 16.4 |
| Connecticut | 0.3994 | 40.8 | 0.4337 | 32.2 | 0.3167 | 8.2 | 0.4730 | 32.7 |
| Delaware | 0.2754 | 23.4 | 0.3150 | 19.3 | 0.2094 | 5.3 | 0.2402 | 13.3 |
| District of Columbia | 0.4854 | 45.1 | 0.5533 | 38.4 | 0.2877 | 7.3 | 0.4672 | 16.3 |
| Florida | 0.3439 | 36.8 | 0.4117 | 31.6 | 0.3186 | 8.8 | 0.2298 | 18.4 |
| Georgia | 0.1214 | 12.9 | 0.1871 | 14.2 | 0.0911 | 2.5 | 0.0219 | 1.7 |
| Hawaii | 0.6052 | 57.8 | 0.6550 | 44.8 | 0.6840 | 17.5 | 0.5425 | 38.2 |
| Idaho | 0.0163 | -1.5 | 0.0152 | -1.0 | -0.0168 | -0.4 | -0.0279 | -2.0 |
| Illinois | 0.2467 | 26.3 | 0.3161 | 24.2 | 0.1973 | 5.4 | 0.0937 | 7.4 |
| Indiana | 0.0146 | 1.5 | 0.0488 | 3.7 | -0.0430 | -1.2 | -0.0133 | -1.0 |
| Iowa | 0.0408 | -4.1 | 0.0018 | 0.1 | 0.0151 | 0.4 | -0.0970 | -7.2 |
| Kansas | 0.0055 | 0.6 | 0.0531 | 3.8 | 0.0814 | 2.1 | -0.0781 | -5.9 |
| Kentucky | 0.1298 | -13.3 | 0.1127 | -8.3 | -0.1251 | -3.2 | -0.1462 | -11.3 |
| Louisiana | 0.0203 | 2.1 | 0.0963 | 7.1 | 0.1066 | 2.8 | -0.1089 | -8.4 |
| Maine | 0.0947 | 8.7 | 0.1083 | 7.4 | 0.0670 | 1.5 | 0.1550 | 9.7 |
| Maryland | 0.4260 | 44.5 | 0.5021 | 37.6 | 0.2754 | 7.6 | 0.3670 | 27.2 |
| Massachusetts | 0.3927 | 41.4 | 0.4361 | 33.1 | 0.3079 | 8.2 | 0.4074 | 29.7 |
| Michigan | 0.0889 | 9.4 | 0.1233 | 9.3 | -0.0022 | -0.1 | 0.0629 | 5.0 |
| Minnesota | 0.1579 | 16.3 | 0.2123 | 15.9 | 0.1824 | 4.9 | 0.0570 | 4.2 |
| Mississippi | 0.1001 | -9.9 | 0.0776 | -5.5 | -0.0980 | -2.3 | -0.1411 | -10.6 |
| Missouri | 0.0023 | 0.3 | 0.0532 | 4.0 | 0.0052 | 0.1 | -0.0758 | -5.9 |
| Montana | 0.0574 | -5.1 | 0.0411 | -2.6 | 0.0089 | 0.2 | -0.0879 | -5.9 |
| Nebraska | 0.0222 | -2.2 | 0.0363 | 2.5 | -0.0327 | -0.8 | -0.1155 | -8.4 |
| Nevada | 0.3589 | 36.5 | 0.3906 | 28.5 | 0.3091 | 7.9 | 0.3424 | 25.8 |
| New Hampshire | 0.3741 | 34.5 | 0.4009 | 27.5 | 0.3796 | 8.8 | 0.4314 | 24.8 |
| New Jersey | 0.5157 | 54.6 | 0.5664 | 43.1 | 0.4135 | 11.3 | 0.5028 | 37.8 |
| New Mexico | 0.0023 | 0.2 | 0.0448 | 3.1 | 0.0043 | 0.1 | -0.0615 | -4.5 |
| New York | 0.4605 | 49.5 | 0.5138 | 39.6 | 0.4209 | 11.5 | 0.3261 | 25.6 |
| North Carolina | 0.0421 | 4.5 | 0.0760 | 5.7 | -0.0019 | -0.1 | -0.0044 | -0.4 |
| North Dakota | 0.1470 | -12.7 | 0.0794 | -5.1 | -0.1511 | -3.1 | -0.2933 | -16.0 |
| Ohio | 0.0004 | 0.0 | 0.0330 | 2.5 | -0.0170 | -0.5 | -0.0278 | -2.2 |
| Oklahoma | 0.0560 | -5.7 | 0.0224 | -1.6 | -0.0539 | -1.4 | -0.1228 | -9.5 |
| Oregon | 0.1801 | 18.6 | 0.2008 | 14.9 | 0.1200 | 3.2 | 0.1618 | 12.4 |
| Pennsylvania | 0.1174 | 12.5 | 0.1889 | 14.4 | 0.0343 | 1.0 | 0.0019 | 0.2 |
| Rhode Island | 0.2359 | 22.1 | 0.2527 | 17.6 | 0.2886 | 6.2 | 0.3729 | 21.2 |
| South Carolina | 0.0135 | 1.4 | 0.0556 | 4.1 | 0.0152 | 0.4 | -0.0537 | -4.1 |
| South Dakota | 0.1696 | -14.7 | 0.1278 | -8.0 | -0.0764 | -1.6 | -0.2410 | -15.3 |
| Tennessee | 0.0260 | -2.7 | 0.0077 | 0.6 | -0.0417 | -1.1 | -0.0728 | -5.7 |
| Texas | 0.1647 | 17.7 | 0.2346 | 18.0 | 0.1435 | 3.9 | 0.0510 | 4.1 |
| Utah | 0.1150 | 11.3 | 0.1530 | 10.8 | 0.0780 | 2.0 | 0.0837 | 6.0 |
| Vermont | 0.2483 | 20.2 | 0.2541 | 15.6 | 0.3054 | 5.2 | 0.3212 | 17.1 |
| Virginia | 0.3315 | 34.9 | 0.4076 | 30.7 | 0.3626 | 9.9 | 0.1617 | 12.7 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Washington | 0.2754 | 29.0 | 0.3149 | 23.8 | 0.1915 | 5.1 | 0.2449 | 19.2 |
| West Virginia | 0.2013 | -18.9 | 0.2005 | -13.4 | -0.1433 | -3.2 | -0.2058 | -14.7 |
| Wisconsin | 0.0980 | 10.3 | 0.1475 | 11.1 | 0.1001 | 2.7 | 0.0248 | 1.9 |
| Wyoming | 0.0000 | . | 0.0000 | . | 0.0000 | . | 0.0000 | . |
| **Urban / Rural** | | | | | | | | |
| Rural | -0.2048 | -157.3 | -0.2122 | -97.9 | -0.1009 | -17.3 | -0.2036 | -143.3 |
| Urban | 0.0000 | . | 0.0000 | . | 0.0000 | . | 0.0000 | . |
| **Bedrooms** | | | | | | | | |
| 0 | -0.4036 | -80.3 | -0.2759 | -50.8 | - | - | - | - |
| 1 | -0.3735 | -138.0 | -0.1964 | -86.8 | -0.3228 | -45.7 | -0.3692 | -94.9 |
| 2 | -0.1809 | -74.7 | 0.0041 | 2.2 | -0.0696 | -18.5 | -0.1973 | -83.3 |
| 3 | -0.1199 | -55.5 | 0.0000 | . | 0.0000 | . | -0.0678 | -36.0 |
| 4 | 0.0000 | . | - | - | - | - | 0.0000 | . |
| **Total Rooms** | | | | | | | | |
| 1 | -0.2858 | -50.8 | -0.0273 | -3.3 | -0.4978 | -19.9 | -0.5310 | -47.7 |
| 2 | -0.2360 | -64.6 | -0.0250 | -3.8 | -0.3943 | -25.0 | -0.4366 | -64.7 |
| 3 | -0.2358 | -69.4 | -0.0220 | -3.5 | -0.3592 | -28.6 | -0.3696 | -79.1 |
| 4 | -0.2066 | -63.9 | 0.0079 | 1.3 | -0.3170 | -27.8 | -0.3173 | -88.7 |
| 5 | -0.1443 | -46.1 | 0.0731 | 11.9 | -0.2345 | -21.3 | -0.2505 | -77.4 |
| 6 | -0.0746 | -23.8 | 0.1408 | 22.3 | -0.1457 | -13.2 | -0.1845 | -58.8 |
| 7 | -0.0169 | -5.1 | 0.1876 | 25.5 | -0.0647 | -5.5 | -0.1213 | -38.0 |
| 8 | 0.0264 | 7.0 | 0.1900 | 20.3 | -0.0267 | -2.0 | -0.0596 | -16.8 |
| 9 | 0.0000 | . | 0.0000 | . | 0.0000 | . | 0.0000 | . |
| **Survey Year** | | | | | | | | |
| 2005 | -0.0351 | -31.5 | -0.0326 | -22.7 | -0.0407 | -9.6 | -0.0347 | -19.7 |
| 2006 | -0.0227 | -20.6 | -0.0240 | -16.9 | -0.0159 | -3.8 | -0.0149 | -8.5 |
| 2007 | -0.0194 | -17.7 | -0.0194 | -13.7 | -0.0139 | -3.3 | -0.0154 | -8.9 |
| 2008 | -0.0166 | -15.3 | -0.0166 | -11.8 | -0.0137 | -3.3 | -0.0165 | -9.7 |
| 2009 | 0.0000 | . | 0.0000 | . | 0.0000 | . | 0.0000 | . |
| **Year Built** | | | | | | | | |
| After 2005 | 0.2887 | 119.8 | 0.2440 | 76.7 | 0.2955 | 37.2 | 0.3387 | 89.4 |
| 2000 – 2004 | 0.2648 | 160.7 | 0.2269 | 107.3 | 0.2576 | 42.5 | 0.2868 | 102.7 |
| 1990 – 1999 | 0.1680 | 117.2 | 0.1267 | 68.7 | 0.1900 | 35.2 | 0.1874 | 77.6 |
| 1980 – 1989 | 0.0720 | 53.9 | 0.0179 | 10.5 | 0.1478 | 29.3 | 0.1428 | 62.1 |
| 1970 – 1979 | 0.0100 | 8.0 | -0.0484 | -30.2 | 0.0800 | 16.4 | 0.1028 | 50.5 |
| 1960 – 1969 | -0.0033 | -2.5 | -0.0528 | -30.1 | 0.0052 | 1.0 | 0.0729 | 35.5 |
| 1950 – 1959 | -0.0220 | -15.8 | -0.0738 | -38.0 | -0.0052 | -1.0 | 0.0545 | 28.8 |
| 1940 – 1949 | -0.0403 | -25.0 | -0.0648 | -28.7 | -0.0518 | -8.9 | 0.0142 | 6.5 |
| Before 1939 | 0.0000 | . | 0.0000 | . | 0.0000 | . | 0.0000 | . |
| **Structure Type** | | | | | | | | |
| Apartments | -0.1108 | -102.5 | - | | - | | - | |
| Attached | -0.0265 | -15.9 | - | | - | | - | |
| Detached | 0.0000 | . | - | | - | | - | |
| **Sum of Squares** | 2,891,050 | | 1,657,042 | | 160,576 | | 806,807 | |
| **Sum of Square Errors** | 8,466,794 | | 6,282,003 | | 459,752 | | 1,374,741 | |
| **RMSE** | 2.0254 | | 2.1464 | | 1.8914 | | 1.5943 | |
| **$R^2$** | 0.2545 | | 0.2087 | | 0.2589 | | 0.3698 | |
| **CV** | 30.3294 | | 32.4623 | | 27.6793 | | 23.3528 | |
| **Observations** | 2,064,077 | | 1,363,642 | | 128,586 | | 540,925 | |