Housing Value, Costs, and Measures of Physical Adequacy

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ABSTRACT

Part of the U.S. Department of Housing and Urban Development's (HUD's) mission is to create quality affordable homes for all. In order to accomplish this, quality must be defined and a method for detecting physically inadequate units developed. Traditionally, researchers have relied on summary indicators of inadequacy provided on the American Housing Survey (AHS) public use data file. This paper re-examines these standard indicators in a hedonic regression framework, using AHS data to develop models that estimate house values and rent. The hedonic models are then used to define a new indicator of physical inadequacy that has a statistically significant negative effect on house values and rents, in contrast to the traditional indicators that are not statistically significant and often have the wrong sign. The new indicator indentifies a substantially larger number of housing units in the U.S. as being physically inadequate, especially single-family units, suggesting that the need for housing assistance is more widespread than generally recognized. Units identified as inadequate under this new criterion are concentrated in the older stock and are disproportionately occupied by households with children. The new criterion also identifies a substantial number of non-seasonal vacant single-family housing units as being physically inadequate, implying that the inventory of existing homes on the market may be effectively overstated. The statistical models used to derive these results also illustrate the practical utility of a large number of variables in different sections of the AHS. Many neighborhood characteristics are shown to have a significant effect on home values, for example, which is information of potentially great value to home owners and local governments.

KEYWORDS: American Housing Survey, hedonic regression, housing quality, inadequacy, neighborhood characteristics

1. INTRODUCTION

An important aspect of the U.S. Department of Housing and Urban Development's (HUD's) mission is its goal of creating quality affordable homes for all. In order to accomplish this effectively, it is necessary to consider affordability and quality in tandem. Affordability may be achieved by neglecting routine maintenance and allowing properties to deteriorate, or failing to replace or renovate very old units to bring them more in line with modern building codes, but few would consider these to be desirable outcomes.

Historically, in order to judge quality of the U.S. housing stock, researchers have typically relied on standard criteria for classifying housing units as physically adequate or inadequate using characteristics of the units collected in the American Housing Survey (AHS). The AHS is funded by HUD and conducted by the U.S. Census Bureau in odd-numbered years, and collects information on a large number of housing characteristics. A number of these characteristics are combined to produce a variable that classifies units as adequate, moderately inadequate, or severely inadequate, and this variable is included on the AHS public use file. It is much more common to accept this traditional classification scheme uncritically than to consider alternative specification, despite the richness of the AHS data set that would permit extensive experimentation with alternatives.

Relying on the standard AHS adequacy classification scheme produces a view of the U.S. housing market where problems of high housing costs relative to income are considerably more widespread than problems of poor quality housing. For example, HUD's latest report to Congress on "Worst Case Housing Needs" (2011) states , "Of the two types of priority problems that qualify as worst case needs, severe rent burden appears far more frequently than severely inadequate housing." An implication is that the problem of physically inadequate housing in the U.S. and its interaction with affordability, although of interest from a theoretic perspective, can often be comfortably neglected in favor of a concentration on affordability problems.

This paper investigates the issue of housing quality in a hedonic regression framework that estimates the impact of various housing characteristics and different definitions of inadequacy on the value of owner-occupied and cost (rent) of renter-occupied housing units. The underlying hypothesis is that inadequate units should have lower values (if owner-occupied) or rents (if renter-occupied), controlling for other characteristics.

Section 2 presents baseline hedonic regression results for owner-occupied single-family and renter-occupied multifamily units. Section 3 following that one proposes new definitions of inadequacy and shows how the new definitions compare to the standard ones that have been used historically when added to the pertinent baseline regression. Section 4 discusses the number of units flagged as inadequate, and the characteristics of the inadequate units and their occupants, under the proposed new classification scheme. Section 5 summarizes the results and offers conclusions.

2. BASELINE REGRESSIONS

2.1. *Hedonic Regression Techniques*

In practice, hedonic regression refers to a technique that estimates the price of a good based on its characteristics. Hedonic price estimation dates back at least to Waugh (1928), although Griliches (1961) and Rosen (1974) are usually credited for establishing it as a widely used technique. One general use of hedonic regression is to estimate a "constant quality" price index for a heterogeneous set of commodities. It is often used this way in housing markets, for example to derive constant quality price indices for new construction (U.S. Census Bureau). It is also used to estimate the marginal impact of a particular characteristic on the price of a commodity.

One of the central problems in estimating a hedonic regression is model specification. This can be particularly challenging in the case of housing, because a housing unit is a complex commodity, with an effectively infinite number of characteristics that can impact its market price. For this reason, any hedonic housing model will fail to capture some relevant characteristics and therefore must be misspecified to a certain extent. Moreover, some characteristics are likely to be collinear, tending to obscure the marginal impact of a particular attribute. The collinearity problem is generally less of an issue when the primary objective of the hedonic model is to drive an index that predicts the value of a housing unit.

Even if prediction their primary intent, however, most hedonic regression estimates eventually end up being used to assess the marginal impacts of particular features. Indeed, a substantial body of hedonic housing market research targets the marginal impact of a particular attribute as the principle objective. This is typically the case when hedonic models are used for policy analysis, as when estimating the value of environmental improvements. A recent example of this is Carruthers, Clark and Renner (2010).

Marginal impacts from hedonic models also have applications for private business decisions. McDonald and McMillen (2007), for example, have argued that hedonic models are useful tools for real estate appraisers because the models provide information on the value of particular attributes. In cases where marginal impacts of particular characteristics are important, as is typically the case, omitted variable bias and collinearity are particularly important, and should be taken into account when developing an empirical strategy.

The empirical strategy employed by the National Association of Home Builders (NAHB) in applying the hedonic regression method to AHS data has been developed over a period of several years. The first example, for single-family house prices, appeared in Emrath (1993) with a subsequent extension to multifamily housing in Emrath (1996). Results from the regressions have been made available to the public on the internet in a form that can be used interactively to estimate house prices, as described in Emrath (2004). The key elements of the NAHB strategy include a substantial effort to clean the data, experimentation with a large number of independent variables, including neighborhood characteristics and interaction terms, and care taken to avoid deleting variables that materially alter estimated coefficients on any of the variables retained.

This strategy is designed to exploit several strengths of the publicly available AHS data set. Although the AHS allocates item non-responses and truncates many variables to preserve respondent confidentiality, these procedures are well documented so that researchers are able to adjust for them. The longitudinal nature of the AHS, revisiting the same housing units year after year, further allows researchers to investigate the way key variables have changed over time, providing an additional useful aid for screening suspect values. Perhaps most significantly, from the perspective of a researcher trying to estimate a single regression equation, the AHS is very large in both dimensions, on a large number of housing attributes as well as a large number of observations. The flattened version of the 2009 public use AHS file, for example, contains 2,776 variables and 73,222 observations. Although this includes vacant units and non-interviews, the number of observations with usable data is nevertheless large enough to accommodate virtually any conceivable single-equation specification and reduce obscuring effects of collinearity.

A potential disadvantage of the AHS sometimes cited in an application like this is its national nature and somewhat limited level geographic detail. Compensating to some extent is the information collected on neighborhood characteristics. For some purposes, information on characteristics of the neighborhood rather than very precise information on the location of the neighborhood may be strength rather than a weakness. Although location indicators identifying housing units to within a fine level of geography, such as a specific census tract or block group, could likely be used to improve the fit of a hedonic regression, this would not provide information on what aspect of a neighborhood is responsible. Yet, information on the impact of being on the waterfront or in a neighborhood with abandoned buildings on property values would typically be of interest to home owners and local policymakers. The NAHB strategy of trying a relatively large number of neighborhood characteristics in the hedonic specification seeks to take as much advantage as possible of this section of the AHS.

2.2 Single-*Family Regressions*

Another feature of the AHS that may be considered a disadvantage is that the current market value of an owner-occupied housing unit is simply the owner's estimates of the home's value, rather than an appraisal or price of an actual transaction, raising questions about the accuracy of owners' valuations. This issue was systematically investigated by Kiel and Zabel (1999). They found that recent buyers on average reported home values 8.4 percent above the stated sales price, while owners who had been in their homes for a longer period of time tended to overvalue their homes by 3.3 percent, so that the average across all owners was a tendency to overvalue their homes by 5.1 percent. However, they also found that, with the exception of length of tenure in the current residence, owners' valuations were not systematically related to characteristics of the owner, housing unit, or neighborhood. If this holds, it suggests that coefficients in a correctly specified hedonic model could be estimated accurately relative to one another, although all coefficients considered as a group may be inflated by roughly 5 percent.

Table 1 shows the results of estimating several specifications of a hedonic model using the 2009 national AHS, where the independent variable is the natural logarithm of the value of single-family detached, owner-occupied home. The models were estimated using NLOGIT 3.0 (the software previously named LIMDEP). Manipulation of the AHS public use file and preparation of a data set for input into NLOGIT was accomplished with SAS.

Efforts to clean the data are centered on removing observations where the dependent or key independent variables have been allocated, top coded, or appear unreasonable. Deleted are observations for manufactured housing units; cases where value or size of the unit is allocated or top coded, where the number of bathrooms or year built is allocated, where home value is 29,000 or less; and, taking advantage of the longitudinal nature of the AHS, where value has fallen to less than one-third of value reported for the same unit in 2007. After these deletions, a total of 20,340 observations from the 2009 AHS were used to generate the ordinary least squares (OLS) estimates shown in Table 1.

The complete list of independent variables used in Table 1 and all other hedonic regression models presented in this paper is as follows:

location indicators

CENT_NE	central city in the Northeast Census region
CENT_MW	central city in the Midwest Census region
CENT_SO	central city in the South Census region
CENT_CA	central city in large California metropolitan areas
CENT_WE	central city in the remainder of the West Census region
BURB_NE	suburban area in the Northeast Census region

BURB_MW	suburban area in the Midwest Census region
BURB_SO	suburban area in the South Census region
BURB_CA	suburban area in large California metropolitan areas
BURB_WE	suburban area in the remainder of the West Census region
NMET_NE	non-metropolitan area in the Northeast Census region
NMET_MW	non-metropolitan area in the Midwest Census region
NMET_SO	non-metropolitan area in the West Census region

The base location omitted from this list is non-metropolitan area in the South Census region.

housing unit characteristics

SIZE1900	size of the unit in 1,000 sq ft if built before 1950; 0 otherwise
SIZE1950	size of the unit in 1,000 sq ft if built from 1950 through 1979; 0 otherwise
SIZE1980	size of the unit in 1,000 sq ft if built from 1980 through 1994; 0 otherwise
SIZE1995	size of the unit in 1,000 sq ft if built from 1995 through 2006; 0 otherwise
SIZE2007	size of the unit in 1,000 sq ft if built after 2006; 0 otherwise
SIZEBF85	size of the unit in 1,000 sq ft if built before 1985; 0 otherwise
SIZE1985	size of the unit in 1,000 sq ft if built from 1985 through 1989; 0 otherwise
SIZEPOST	size of the unit in 1,000 sq ft if built after 1990; 0 otherwise
LOTSIZE	size of the lot in acres for single-family units
BATHS	number of full bathrooms in the unit
HALFB	number of half bathrooms in the unit
BEDRMS	number of bedrooms in the unit
DINING	number of dining rooms in the unit
FAMRM	number of family rooms in the unit
OTHROOMS	number of rooms other than baths and bedrooms for multifamily units; other than baths, bedrooms, dining rooms and family rooms for single-family units
BA_MW	indicator for full or partial basement in the Midwest Census region
BA_SO	indicator for full or partial basement in the South Census region
BA_CA	indicator for full or partial basement in large California metropolitan areas
GARAGEX	indicator for garage or carport included with unit
FIREPLAC	indicator for presence of a fireplace
AC_MWSO	indicator for central air conditioning in the Midwest and South Census regions
UDISH	indicator for presence of a working dishwasher in the unit
UDRY	indicator for presence of a working clothes dryer in the unit

neighborhood and multifamily building characteristics

GREEN	indicator for open spaces within 1/2 block
COMRECR	indicator for presence of community recreational facilities
COMGATE	indicator for a unit lying within a gated community
XWATER	indicator for property not on the waterfront, but with a body of water within 1/2 block
XWFPROP	indicator for waterfront property
WFP_NE	indicator for waterfront property in the Northeast Census region
WFP_MW	indicator for waterfront property in the Midwest Census region
WFP_SO	indicator for waterfront property in the South Census region
WFP_CA	indicator for waterfront property in large California metropolitan areas
WFP_WE	indicator for waterfront property in the remainder of the West Census region
XTRAN	indicator for neighborhood with satisfactory public transportation
XTR_MET	indicator for satisfactory neighborhood public transportation within metropolitan areas

XSHOP	indicator for neighborhood with satisfactory shopping
SHP_MET	indicator for satisfactory neighborhood shopping within metropolitan areas
UELEV	indicator for unit within a multifamily building, on a floor with access to an elevator
UACCESSB	indicator for entry system that restricts access to the building
FLOOR_3	indicator for unit in a building with 3 floors
FLOOR_49	indicator for unit in a building with 4 to 9 floors
FLOOR_10	indicator for units in building with 10 or more floors
FIFTY_1	indicator for unit in a building with 1 floor and fifty or more housing units
BARCL	indicator for buildings within 1/2 block of the unit with metal bars on their windows
ABAN	indicator for abandoned or vandalized buildings within 1/2 block of the unit
BADROADS	indicator for roads in need of repair within 1/2 block of the unit
COMCRIME	indicator for serious crime in the neighborhood within the past year
COMODOR	indicator for unit in a neighborhood with smoke, gas, or bad smells
XSTNOISE	indicator for unit in a neighborhood with heavy street noise or traffic
JNK_MET	indicator for trash/litter/junk within 1/2 block of the unit in metropolitan areas
JNK_NM	indicator for trash/litter/junk within 1/2 block of the unit outside of metropolitan areas
COM1	indicator for businesses or institutions within 1/2 block of the unit
COM2	indicator for factories/industrial structures within 1/2 block of the unit
MB_MET	indicator for mobile homes within 1/2 block of the unit in metropolitan areas
MB_NM	indicator for mobile homes within 1/2 block of the unit outside of metropolitan areas

Indicators of physical inadequacy

NEW_INAD	unit inadequate according to proposed new criteria described in the next section
AHS_MOD	unit either moderately or severely inadequate according to the traditional AHS criteria
AHS_SEV	unit severely inadequate according to the traditional AHS criteria

The location indicators cross the four principal census regions with the urban status (central city, suburb, and non-metro), which is generally the greatest level of usable geography available in the AHS. The AHS does identify certain metropolitan areas (based on the definitions and boundaries of metropolitan areas that prevailed in 1980), but there are generally too few observations in a metropolitan area to treat each them separately in the model. However, a number of the large California metropolitan areas were carved out as a separate "region" distinct from the rest of the west, a procedure first employed in Emrath (1995). The metropolitan areas included in the California region are Bakersfield, Fresno, Los Angeles-Long Beach, Modesto, Oakland, Orange County, Riverside-San Bernardino, Sacramento, San Diego, San Francisco, San Jose, Santa Barbara-Santa Maria, Santa Rosa, Stockton-Lodi, Vallejo-Fairfield-Napa, and Ventura. It is well known that home values tend to be high in many of these areas, and being in a central city or suburban location within one of the California metropolitan areas has the strongest effect on house value of any of the location indicators. The location indicator excluded because the models are estimated with a constant term is the non-metropolitan South, so the coefficients on the location indicators in Table 1 are estimated percentage changes in value relative to a location in the non-metropolitan South.

An additional specification issue in hedonic regression is choice of functional form. Although the term hedonic is often used simply to indicate a regression that estimates price of a good as a function of its characteristics, there is economic theory that underlies the technique. Because both production costs and utility of a particular good typically both change with changes in its characteristics, a question arises as to whether the hedonic regression captures a demand or supply relationship. The answer is essentially both, as equilibrium in a hedonic model represents a point of tangency between buyer and seller offer curves. The relationship between price and a particular characteristic traces an envelope of these tangency points, a point emphasized by Rosen (1974). Although the first derivative of a desirable characteristic is generally positive, as increasing a desirable characteristic in a commodity usually coincides with a higher production cost, economic theory otherwise provides little guidance on choice of functional form. Although use of the semi-logarithmic specification in Table 1 has been commonplace dating back as far as a paper by Court (1939), in the absence of a theoretic justification some testing of alternative forms seems desirable. To address this, all models considered in this paper were initially estimated by employing a Box-Cox functional form that transforms the dependent variable (house value or rent) according to the following formula:

$$f(\lambda) = (y^{\lambda} - 1) / \lambda$$

where λ is a free parameter to be estimated. This specification includes linear (λ=1) and semi-logarithmic (λ=0) models as special cases. This functional form was first employed by NAHB to analyze AHS data in Emrath (2002) for single-family housing and in Emrath (2001) for multifamily housing.

Table 2 shows likelihood ratio tests for each of the semi-logarithmic models shown in Table 1 against an alternative of the more general Box-Cox specification. In each case, the estimated value of λ is relatively close to zero—.009 or smaller in absolute value—and not statistically significant even at, say, a .1 significance level. In other words, the likelihood ratio tests fail to reject any of the semi-logarithmic specifications in Table 1 in favor of the more general form. Moreover, even if the Box-Cox version of the model were to be used, with an estimated value of λ so close to zero, it would make little practical difference. Hence, the semi-logarithmic specification was chosen for the models shown in Table 1. Because of the logarithmic transformation, coefficients in Table 1 have the interpretation of percentage change in home value attributable to a particular independent variable.

Model 1 in Table 1 shows the result of regressing the logarithm of home value on locational indicators and housing unit characteristics. Model 2 includes all of the variables in Model 1 plus 23 neighborhood characteristics, most of them statistically significant. The adjusted R^2 statistic, a conventional measure of the fit of the model, is higher for Model 2 than Model 1.

Table 2 also shows likelihood ratio tests of Model 1 against a model with a constant term as the only regressor, and of Model 2 against Model 1. The likelihood ratio test is applicable under relatively general conditions that can be used to evaluate all models considered in this paper, including those that are non-linear and estimated with a technique other than OLS. The likelihood ratio tests in Table 2 reject a constant-only model in favor of Model 1, and Model 1 in favor of Model 2.

Coefficients on the independent variable common to models 1 and 2 are relatively stable across specifications, especially the housing unit characteristics. Among the location indicators, the smallest coefficients in Model 1 (for CENT_MW) changes sign in Model 2 and the second smallest (for CENT_SO) becomes insignificant at the .1 level.

Housing characteristics employed in the models include size of the home crossed with the year it was built. There is a systematic tendency for a square foot of living space to be worth more for homes that were built more recently. This may reflect lower maintenance or operating costs that are capitalized into the value of the home, or more stringent building codes that increase perceived safety of the homes and their construction costs. The age of the home may also in part be acting in part as a proxy for floor plans that change over time in response to consumer preferences, or other features not captured in the data set.

Interactions between location and many of the housing unit characteristics and all of the neighborhood characteristics were tried in preliminary versions of the models, and retained in the specifications shown in Table 1 where they made a noticeable difference. Among the housing unit characteristics, the strongest effects on home values are associated with presence of a basement if this occurs in the "California metro" region, followed by the addition of a full bathroom. The difference in the cost of excavating and constructing a basement relative to the alternatives can vary substantially with location, depending on soil conditions and code requirements for a foundation in the absence of a basement.

All of the housing unit characteristics included in Table 1 have a positive impact on home values that is significant at the .1 level or better. The 23 neighborhood characteristics in Model 2 include those with both positive and negative impacts on value. The strongest positive estimate impacts on value among the neighborhood characteristics are associated with a location directly on the waterfront. The strongest negative impacts come from the presence of abandoned buildings in the neighborhood. Coefficients on two of the neighborhood variables, JNK_NM and COM2, are not significant at the .1 level, but the sign of the coefficients and their magnitude relative to other coefficients estimated in the models in Table 1 are plausible.

2.3 *Multifamily Regressions*

Table 3 shows estimated results for several specifications of a model where the dependent variable is a Box-Cox transformed version of monthly rent for multifamily units, defined as units in structures with five or more units. Manufactured housing is excluded. The measure of rent is based on gross rent for units where no fuel (electricity, gas, or oil) is included in the rental payment. Gross rent includes rent paid to the property owner as well as the cost of non-telecommunication utilities, irrespective of who pays them. In order to remove ambiguity and achieve a consistent measure across observations, it is necessary to use gross rent rather than simply the payment made to the property owner, due to the substantial variation that exists in practices for including utility costs in the rental payment. Some ambiguity remains due to differential treatment of items such as water and sewer payments, but these are typically small relative to the payment for energy.

The data set remains the 2009 national AHS. Efforts to clean the multifamily rental data include deleting cases where the tenant is occupying the unit without paying cash rent; where the occupant reports that the unit is public housing, that the government subsidizes the rent or limits the rent through rent control or stabilization, or that the rent is adjusted because the tenant is related to the owner; where size of the unit is allocated or top coded; where rent or the number of bathrooms is allocated; or where rent has either tripled or fallen to less than one-third of value reported for the same unit in 2007. After these deletions, a total of 2,645 observations from the 2009 AHS were used to generate the regression estimates shown in Table 3.

The regressions in Table 3 are a Box-Cox functional form with λ, an additional parameter that is estimated with the rest through a maximum-likelihood procedure. Because of this, the adjusted R^2 statistic is not available. As a substitute, the Prediction Criterion (PC) introduced in Amemiya (1980) is provided as an alternate goodness of fit measure, where a smaller PC indicates a better fit.

Model 1 in Table 3 shows the result of regressing the transformed version of rent on locational indicators and housing unit characteristics. Model 2 includes all of the variables in Model 1 plus a number of characteristics that pertain to the overall building or community surrounding it. According to PC, Model 2 is preferred to Model 1. Table 4 shows likelihood ratio tests for the models in Table 3. These tests reject a constant-only model in favor of Model 1, and Model 1 in favor of Model 2 against a model with a constant term as the only regressor, and of Model 2 against Model 1. Both the PC and likelihood ratio tests indicate that a model that includes building and neighborhood characteristics is appropriate.

For each of the models considered in Table 3, Table 4 also includes likelihood ratio tests for linear and semi-logarithmic models against the alternative of the Box-Cox specification.   In each case, both the linear and semi-logarithmic forms are rejected in favor the more general alternative of the Box-Cox regression that appears in Table 3.

The estimated value of λ varies somewhat across the table, but remains in the neighborhood of -.4. Analogous to the results shown for the single-family regressions, coefficients on the independent variable common to models 1 and 2 are relatively stable across specifications in Table 3, although coefficients on two of the housing unit characteristics (HALFB and FIREPLAC) become significant with the addition of building and neighborhood characteristics to the model.

Because of the Box-Cox functional form, coefficients associated with independent variables no longer have the interpretation of a percentage change in the dependent variable.   As an aid to interpretation, a few examples of marginal impacts are included in the exposition.   If a unit with characteristics that produced an estimated monthly rent of $1,000 in the non-metropolitan South were located instead in a Southern central city, the coefficient in Model 2 in Table 3 implies that its monthly rent would increase by $190. If the original unit were located in a suburb in the "California metro" rather than the non-metropolitan South, its rent would increase by $962.

Housing characteristics considered in the rent models include size of the unit crossed with the age of year in which the structure was built. Although Table 3 shows a systematic tendency for a square foot of living space to be worth more in structures that were built more recently, this is shown in considerably less detail than in the single-family model, with vintage differences becoming undetectable among units built before 1985. This may be a symptom of the smaller number of observations used to generate Table 3, but renters may also be less knowledgeable than owners about the vintage of the building they are living in. Neither the coefficient on SIZEBF85 or SIZE1985 is significant at the .1 level, but both are retained in model under the argument that that the hypothesis that rents increase along with square footage of the unit remains reasonable worth sustaining, and the relative magnitude of the coefficients is consistent with the hypothesis that the value of a square foot of living space is higher in newer units.

The coefficient on OTHROOMS is also relatively small and not significant at the .1 level. This coefficient is estimated in a model that controls of a number of other characteristics, including square footage of the unit, bathrooms, and bedrooms. It is reasonable to suppose that an extra wall partition in an apartment that doesn't result in a larger unit, or an extra bed or bathroom, would add relatively little to the rent that can be charged.   For a hypothetic unit that rents for $1,000 per month, the coefficient in

Model 2 in Table 3 implies that an extra room without a corresponding increase in square footage would increase estimated monthly rent by $8.

A number of building characteristics have a significant impact on rents in Model 2, particularly those related to the number of floors and units in the building. Tall buildings and buildings containing a large number of units tend to be more common in places where land is expensive, and the indicators for these characteristics are acting as a proxy for this tendency in the model. Some neighborhood characteristics have a significant effect, but far fewer than in the single-family models shown in Table 1. Again this may partly reflect the smaller number of observations used to estimate the multifamily models, but it may also be that renters in multifamily structures feel more isolated from conditions in the surrounding neighborhood and therefore do not attach the same value to these conditions as single-family home owners. For a hypothetic unit that rents for $1,000, the coefficient in Model 2 in Table 3 implies that a waterfront location increases rent for the unit by $73.

3. PHYSICAL INADEQUACY

Because an important part of HUD's mission is to create quality housing for all, it is not surprising that a survey like the AHS, which is funded by HUD for the purpose of tracking the condition of housing in the U.S., collects considerable information on unit quality. Combining this information into a single indicator is far from a trivial exercise, however. The multidimensional nature of housing means that a meaningful analysis of housing quality can't be reduced to one or two simple characteristics, a point that has been emphasized by Weicher (1979). One implication of this is that data sets that contain information on only a limited number of housing characteristics, such as the American Community Survey, are not useful for detecting physical inadequacy. In fact, it is difficult to imagine a data set other than the AHS that could be effectively used for this purpose.

The AHS had traditionally provided two standards for housing inadequacy—moderately inadequate and severely inadequate. A housing unit is classified as severely inadequate in the AHS if it has any one of the following conditions:

1) less than 2 full bathrooms without hot and cold running water, or without bathtub or shower, or without a flush toilet, or with shared plumbing
2) respondent who reports being cold for 24 hours or more and at least 2 breakdowns of heating equipment lasting longer than 6 hours
3) respondent reporting that the household does not use electricity
4) exposed wiring, plus a lack of electrical outlets in every room, plus fuses that have blown more than twice

5) at least 5 of the following
    i) outside water leaks
    ii) inside water leaks
    iii) holes in the floor
    iv) open cracks in the inside walls or ceilings
    v) an area of peeling paint larger than 8 x 11
    vi) seeing rats recently

A unit that is not severely inadequate is moderately inadequate in the AHS if it has any one of the following conditions:

1) at least 3 of the conditions listed in 5) above
2) more than 2 6-plus hour toilet breakdowns
3) main heating equipment consisting of unvented room heaters
4) lack of complete kitchen facilities

Although these criteria are relatively complex, they exploit only a fraction of the data collected in the AHS that could be used as a basis to classify units as adequate or inadequate.

The basic structure of the AHS summary inadequacy definitions has been in place for decades, and appears to have undergone relatively little scrutiny during that time. The changes that have taken place seem to be the result of attempts to streamline the AHS data set rather than to refine or improve the adequacy classification scheme. For example, the definitions of severe and moderate inadequacy were simplified slightly in 2007, removing additional criteria based on problems in common areas of multifamily structures (such as lack of lighting, broken stairways, loose or no rails on stairs), when questions on some of these characteristics were deleted from the AHS questionnaire.

Moreover, when the concepts of moderate and severe inadequacy were originally defined, although considerable thought went into the process, it was nevertheless done in a relatively ad hoc fashion, without trying alternate specifications in an economic model (based on personal communication from David Crowe, who was involved in the development of the AHS in the 1970s).

This section of the paper proposes new summary criteria for determining the physical adequacy of housing units that uses somewhat different AHS variables. The new definition of inadequacy presented in this paper, indentified in the tables as NEW_INAD, flags a single-family structure as physically inadequate if it has any one of the following

1) missing siding
2) broken windows

3) holes , cracks, or crumbling in the foundation
4) sagging roof
5) holes in the roof

These characteristics were chosen because, individually as well as collectively, they tend to lower the value of single-family homes, controlling for other factors. Repairing building conditions such as these would in general cost a significant amount of money, time, and effort to correct, so it is theoretically plausible that would they tend to have a depressing effect on the reported value of single-family homes.

To illustrate this, Model 3 in Table 1 adds NEW_INAD to Model 2. The coefficient is significant and indicates that, controlling for the other variables in the model, NEW_INAD reduces value of the unit by roughly 11 percent.

Models 4 and 5 introduce the standard AHS measures of inadequacy, AHS_MOD and AHS_SEV into the hedonic specification. Although it would be unfair to expect these traditional inadequacy indicators to perform as well as NEW_INAD, which was constructed to work well in the model, the weakness of the traditional indicators in the hedonic specification is perhaps surprising. The estimated coefficients indicate that AHS_MOD reduces house value by 1.4 percent, while AHS_SEV increases house value by 3.6 percent. Neither effect is significant at the .1 level. Among the three alternative indicators of inadequacy in Table 1, only NEW_INAD improves the fit of the model as indicated by the adjusted R^2. The hypothesis tests in Table 2 also reject Model 2 in favor of Model 3, but fail to reject Model 2 in favor of either Model 4 or Model 5.

An advantage of the conditions used to define NEW_INAD for single-family homes is that they are based on questions asked in all AHS interviews, including interviews conducted for vacant units, allowing investigation into the condition of vacant as well as occupied housing units.

A drawback to the conditions used in single-family definition of NEW_INAD is that they do not allow for a consistent definition across structure type—i.e., they are not generally applicable to multifamily structures. Most of the above-mentioned conditions used in single-family NEW_INAD were cited by very few to no occupants of multifamily rental units in the 2009 AHS. This probably not surprising, given the nature of the characteristics, which refer to the condition building rather than a particular unit in a building. Depending partly on the location of their unit within the building, occupants of multifamily structures may be unaware of the condition of, for example, the foundation or roof. Indeed, the occupant may not consider these to be problems if located in a part of the structure remote form his or her own unit.

Hence, the proposed definition for NEW_INAD for multifamily units is based on a different set of characteristics. NEW_INAD indicates that a multifamily housing unit is inadequate if it has is any of the following:

1) lack of a kitchen sink
2) lack of a bathroom sink
3) open cracks in the inside walls, or ceilings
4) a breakdown of the sewage system since the last interview
5) lack of built-in equipment designed to distribute heat throughout the unit in climates with 4,000 of more heating degree days.

These conditions are generally observable by occupants of the multifamily unit. Except for breakdown of the sewage system, the conditions are also based on AHS questions asked in interviews for both vacant and occupied housing units.

A unit is identified as having a lack of built-in heating equipment designed to distribute heat throughout the unit if it has no main heating equipment, or if the main heating equipment is one of the following: vented room heaters burning kerosene gas or oil, unvented room heaters burning kerosene gas or oil, portable electric heaters, or cooking stove. In the AHS, the only one of these that is used in the definition of inadequate housing is unvented room heaters. Yet, all types of room heaters, portable electric heaters, and gas or electric cooking stoves are often cited as safety hazards.

For example, the U.S. Consumer Product Safety Commission (2009) has warned of fire hazards from space heaters and urged consumers to be careful about where they place space heaters, to keep children and pets away from them, to never leave them on when sleeping or away from home, to only use the appropriate type of fuel, and to only use heaters that have been tested to the latest standards. The same document explicitly instructs consumers never to use electric or gas stoves to heat a home, because they are not intended for that purpose and can cause carbon monoxide poisoning as well as fires. In another document, the U.S. Consumer Product Safety Commission (2011) warns of fire hazards associated with portable electric heaters and provides a long list of safety recommendations, many of which are similar to the recommendations issued for space heaters.

The multifamily version of NEW_INAD assumes that reliance on any heating equipment that requires so much care on the part of tenants to operate safely is a reasonable indicator of the physical inadequacy of the unit, as is a total lack of heating equipment, in an area where heating equipment is needed. The cut-off used to identify areas where heating is needed is a climate with at on average at least 4,000 heating degree days.

The information on climate available in the AHS public use file is somewhat restricted. Climate data is collapsed into six zones, based on both heating and cooling degree days, and sometimes suppressed for confidentiality reasons. The first three of the zones (coldest, cold, and cool) are characterized by at least 4,000 heating degree days. For a picture of the area captured by this degree day requirement, the standard reference for this is the set of maps produced by the National Oceanic and Atmospheric Administration. In the central part of the country, 4,000-plus heating degree days roughly coincides with the area north of Missouri's southern border. Toward the east coast, the line of demarcation drifts upward and only the northern part of Virginia has 4,000-plus heating degree days. On the west coast, the 4000-plus heating degree zone starts well north of San Francisco. In mountainous areas, the cut-off is determined by elevation as much as latitude. Around the Sierra Nevada and Rocky mountain ranges, the 4000-plus heating degree zone extends well to the south, but much of this area is sparsely populated.

Again, characteristics for the multifamily version of NEW_INAD were chosen because, individually and collectively, they have a depressing effect on the dependent variable in question, in this case monthly rent. When considering the depressing effect of lack of built-in heating in colder climates on rent, it is useful to recall that sample used to estimate the models in Table 3 excludes cases where utility payments included in rents, so the estimated impacts on rents are impacts on rents exclusive of utility costs.

Analogous to the treatment of inadequacy in single-family regressions, competing definitions of inadequacy are added to Model 2 one at a time in Table 3. Model 3 adds the proposed new definition of physical inadequacy. The coefficient on this variable is statistically significant and implies that, for a hypothetic unit that would otherwise rent for $1,000, inadequacy under this new definition reduces rent by $42.

In contrast, in models 4 and 5, coefficients on the standard AHS measures of inadequacy, AHS_MOD and AHS_SEV, are insignificant and have the wrong signs. For the hypothetic $1,000 per month rental apartment, the coefficients in these models imply that AHS_MOD would increases rent by 25 cents and AHS_SEV would increase rent by $67. The PC statistics favor Model 3 over any of the alternatives in Table 3. The hypothesis tests in Table 4 also reject Model 2 in favor of Model 3, but fail to reject Model 2 in favor of either Model 4 or Model 5.

Of the three indicators of physical inadequacy considered, the statistics presented in tables 1 through 4 consistently favor the new definition proposed in this paper over the traditional summary measures provided on the AHS data file in the hedonic models that explain house value and rents.

4. CHARACTERISTICS OF INADEQUATE UNITS

The first question that arises in evaluating a proposed definition of inadequacy is the number of housing units that it in fact classifies as inadequate. Table 5 shows the number of housing units classified as inadequate under both of the standard summary criteria in the AHS, as well as under the new criterion proposed in this paper.

The standard criteria in the AHS tend to classify a small *share* of single-family units as inadequate relative to multifamily. According to these criteria, 1.3 percent of occupied single-family and 2.9 percent of occupied multifamily units are severely inadequate and 3.5 percent of occupied single-family are at least moderately inadequate, compared to 10.1 percent of the occupied multifamily units. However, because a large proportion of the U.S. housing stock consists of single-family housing, the standard AHS measures fairly equal *numbers* of occupied inadequate single-family and multifamily units—2.7 and 2.6 million, respectively, in the case of the moderately or severely inadequate category.

In contrast, the new criterion proposed in this paper, although based on somewhat different characteristics depending on structure type; captures near-equal shares of occupied single-family and multifamily units—classifying 8.5 percent of single-family and 8.3 percent of multifamily units as inadequate. This translates into a larger number of inadequate occupied housing units—8.8 million (6.7 million single-family and 2.1 million multifamily) compared to only 5.3 million for the most inclusive of the traditional AHS inadequacy measures. The tables published on the Census Bureau's web site based on the 2009 national AHS show 5.7 moderately or severely inadequate occupied units rather 5.3 million, because the Census published tables include 0.4 million inadequate manufactured housing units, and the tabulations in this paper exclude manufactured housing.

Because the proposed new inadequacy criterion relies primarily on characteristics that are collected in AHS interviews conducted for both vacant and occupied units, it can be applied to vacant housing units. Table 5 also shows estimates of the number of inadequate non-seasonal vacant units, where non-seasonal vacant units exclude vacant units that are coded as seasonal, migratory, or held for occasional use. These units are excluded from the tabulations, because adequacy standards may be different for housing units not intended for year-round occupation. The share of non-seasonal vacant multifamily units that are inadequate is only slightly higher than the share for occupied units, but the inadequate share of non-seasonal single-family units is over 19 percent. Knowledge of this statistic could significantly alter the way industry observers evaluate the inventory of existing units on the market for sale or rent.

Table 6 shows housing units by the year they were built, both for all units and for those that are inadequate under the definition of inadequacy proposed in this paper. The inadequate units tend to be relatively old. Roughly a third of inadequate units were built before 1940, compared to 16 percent of all occupied and non-seasonal vacant units. These results are not surprising as older units have had more time to undergo wear and tear, and for problems of neglected maintenance to accumulate.

Table 7 partitions the housing stock by geography rather than by vintage. Compared to housing units in general, the inadequate units are less often found in suburbs; more often in central cities and non-metropolitan areas. There is a partial exception to this general rule for non-seasonal vacant multifamily housing. Within that category, the inadequate units are more concentrated in central cities, but not in non-metropolitan areas. Because the housing stock tends to be older in central cities and outside of metropolitan areas, the results in Table 7 are generally consistent with those shown in Table 6.

Of the over 8.8 million households living in inadequate housing units in the U.S. as of 2009, nearly 5.2 million are owners; 3.7 million are renters (Table 8). Fewer than half a million of owners and renters combined living in inadequate units are spending 30 percent of more of their incomes on housing. This means that most occupants of inadequate units are not counted among the cost-burdened and represent a net addition to the number of American households with housing problems. All of the households who are both cost-burdened (spending at least 30 percent of income on housing) and living in inadequate units earn less than 50 percent of Area Median Income (AMI).

Renters living in inadequate housing are particularly concentrated at the lower end of the income distribution. Nearly 40 percent of them earn less than 30 percent of AMI. Home owners living in inadequate housing are more evenly spread across the income distribution. More than a quarter of them earn at least 120 percent of AMI. It seems reasonable to suppose that many owners of inadequate units in this income range have resources to upgrade their existing units or move to new ones if they so choose. These owners may therefore not be appropriate targets for housing assistance in the conventional sense, but an educational effort that provides information about property repair and maintenance could be worthwhile.

Table 9 shows that the problems of physically inadequate housing persist across major racial and ethnic categories. Over 76 percent of homeowners living in inadequate units are non-Hispanic white, and this is only about 2 percent below the incidence of 78 percent of non-Hispanic whites among all homeowners. In fact, among the groups shown in Table 9, only non-Hispanic black households are over-represented among the homeowners in inadequate units. The racial and ethnic breakdown of renters living in inadequate units is very similar to the breakdown for all renters. In Table 9, the only group that is over-represented in the inadequate column compared to its share among all renters is the Hispanic, and even here the difference is less than one percentage point.

In contrast to the relatively egalitarian distribution of physically inadequate housing across racial and the ethnic lines, Table 10 shows that there are particular categories of households who are disproportionately impacted by problems of inadequate housing, and these are families with children. The effect is strongest for single parents and other households that are not headed by a married couple but nevertheless contain children under age 18. Although these non-married households with children account for 6.7 percent of all homeowners, they account for 11.6 of owners living in inadequate housing. Non-married households with children also account for 19.7 percent of renters, but 26.1 percent of renters in inadequate units.

5. SUMMARY AND CONCLUSION

This paper has presented baseline hedonic regression models that estimate house value for owner-occupied units and rents for rental apartments, building on models that have been developed by NAHB over the past two decades, based on data from the 2009 national AHS. Distinguishing features of these models include extensive use of the allocation flags and other features of the AHS public use file to clean the data before estimation (which includes exploiting the longitudinal nature of the survey and comparing the same unit across years to detect outliers), the inclusion of interaction terms that combine information on size of the units with the year they were built, and explanatory variables drawn from many sections of the survey, including the section that collects information on neighborhood characteristics.

A relatively large number of neighborhood characteristics have economically and statistically significant effects on the dependent variables, particularly on the value of owner-occupied single-family housing, This subset of the results by itself has a number of potential uses, especially at the local level. For example, the results could be used by home owners associations or local governments to estimate how certain public policies (such as providing public transportation, or finding a use for abandoned buildings) are likely to impact home values in particular neighborhoods. Moreover, it is not obvious that these effects could be estimated from any alternative data source that currently exists.

This paper combines the regression models with information from the housing quality and related sections of the AHS to develop a new summary indicator of physically inadequate housing. This is another line of research that would be difficult or impossible to pursue without the information contained in the AHS. The new inadequacy indicator proposed in this paper is based primarily on conditions of the building (such as missing siding, holes in the roof, and broken windows) for single-family units, and conditions that are more readily observed from inside the unit (such as lack of a bathroom or kitchen sink and reliance on hearting equipment that poses a risk, or no heating equipment at all, inside the unit). This new indictor of inadequacy has a statistically significant and negative effect on house values and rents—in contrast to the traditional summary indicators of inadequacy that are provided the public use AHS file, which are not significant and often have the wrong sign.

The new indicator also indentifies a substantially larger number of housing units in the U.S. as physically inadequate, especially single-family units. The inadequate units are strongly concentrated in the older housing stock and in geographic areas when the stock tends to be older, including both central cities and outlying non-metropolitan areas.

Physical adequacy and affordability are two sides of the same coin, in that affordability may be achieved by neglecting maintenance and repairs that leads to conditions such broken windows or holes in the roof—or failure to replace or upgrade older units that lack sinks or safe central heating equipment in colder climates—but achieving pure affordability through these means is not in general a desirable outcome.

Very few of the households identified by the new indicator as living in physically inadequate housing are also suffering from housing costs that are high relative to their incomes. Therefore, the larger number of households living in inadequate units represents primarily a net addition to the estimated number of U.S. households experiencing housing problems that need to be addressed in some fashion. Some of the households living in inadequate units are owners who appear to be relatively well off, with incomes of at least 120 percent of the area median and housing costs under 30 percent of this income.

From a public policy perspective, the remedy for these cases may primarily be educational, providing information about recommended repair and maintenance schedules, or how to cost effectively upgrade older structures to more current standards. Even net of these relatively well-off cases, however, the estimates of inadequate housing presented in this paper indicate that the need for housing assistance in the conventional sense is more widespread than generally recognized. A disproportionate share of households suffering from inadequate housing are households with children.

The new indicator proposed in this paper can also be applied to estimate the number of inadequate vacant housing units. The resulting estimate is well over a million inadequate non-seasonal vacant housing units in the U.S., with a particularly high rate of inadequacy found among non-seasonal vacant single-family units. An implication of this is that the effective inventory of existing single-family units available on the market may be overstated, if it is assumed these units are ready to be sold to prospective full-time occupants without substantial repairs or upgrades.

Table 1. House Value: ordinary least squares (OLS regression) estimates

Dependent variable: natural logarithm of value of owner-occupied single family detached housing units

	Model 1		Model 2		Model 3		Model 4		Model 5	
Constant	10.644	(.421)	10.725	(.423)	10.738	(.424)	10.727	(.424)	10.724	(.423)
location indicators										
CENT_NE	.777	(.076)	.637	(.066)	.627	(.065)	.635	(.066)	.636	(.066)
CENT_MW	.016*	(.024)	-.083	(.030)	-.078	(.030)	-.084	(.030)	-.083	(.030)
CENT_SO	.123	(.021)	.035*	(.024)	.036*	(.024)	.035*	(.024)	.035*	(.024)
CENT_CA	1.156	(.109)	1.039	(.099)	1.034	(.099)	1.037	(.099)	1.039	(.099)
CENT_WE	.693	(.067)	.567	(.059)	.562	(.058)	.565	(.059)	.567	(.059)
BURB_NE	.866	(.080)	.731	(.070)	.724	(.069)	.730	(.070)	.731	(.070)
BURB_MW	.144	(.024)	.045	(.026)	.046	(.026)	.044	(.026)	.045	(.026)
BURB_SO	.194	(.022)	.119	(.024)	.120	(.024)	.118	(.024)	.119	(.024)
BURB_CA	1.293	(.122)	1.163	(.110)	1.156	(.110)	1.161	(.110)	1.163	(.110)
BURB_WE	.753	(.071)	.625	(.062)	.619	(.061)	.623	(.062)	.625	(.062)
NMET_NE	.435	(.047)	.389	(.043)	.385	(.043)	.387	(.043)	.389	(.043)
NMET_MW	-.088	(.023)	-.111	(.024)	-.112	(.024)	-.112	(.024)	-.111	(.024)
NMET_WE	.596	(.059)	.580	(.057)	.573	(.056)	.578	(.057)	.580	(.057)
housing unit characteristics										
SIZE1900	.055	(.008)	.056	(.008)	.058	(.008)	.056	(.008)	.056	(.008)
SIZE1950	.072	(.008)	.067	(.008)	.067	(.008)	.067	(.008)	.067	(.008)
SIZE1980	.100	(.011)	.094	(.010)	.094	(.010)	.094	(.010)	.094	(.010)
SIZE1995	.111	(.012)	.107	(.011)	.106	(.011)	.107	(.011)	.107	(.011)
SIZE2007	.129	(.018)	.124	(.017)	.123	(.017)	.124	(.017)	.124	(.017)
LOTSIZE	.009	(.002)	.012	(.002)	.012	(.002)	.012	(.002)	.012	(.002)
BATHS	.213	(.021)	.193	(.019)	.191	(.019)	.193	(.019)	.193	(.019)
HALFB	.122	(.013)	.115	(.013)	.113	(.012)	.115	(.013)	.115	(.013)
BEDRMS	.040	(.006)	.044	(.006)	.045	(.006)	.044	(.006)	.044	(.006)
DINING	.068	(.010)	.067	(.009)	.067	(.009)	.067	(.009)	.066	(.009)
FAMRM	.083	(.011)	.074	(.010)	.074	(.010)	.074	(.010)	.074	(.010)
OTHROOMS	.039	(.006)	.038	(.006)	.040	(.006)	.038	(.006)	.038	(.006)
BA_MW	.088	(.018)	.085	(.018)	.085	(.018)	.085	(.018)	.085	(.018)
BA_SO	.193	(.023)	.182	(.022)	.180	(.022)	.182	(.022)	.182	(.022)
BA_CA	.442	(.077)	.452	(.076)	.449	(.075)	.452	(.076)	.452	(.076)
GARAGEX	.052	(.012)	.039	(.011)	.036	(.011)	.039	(.011)	.039	(.011)
FIREPLAC	.141	(.015)	.126	(.014)	.126	(.013)	.126	(.014)	.126	(.014)
AC_MWSO	.148	(.018)	.125	(.016)	.118	(.016)	.124	(.017)	.125	(.016)
neighborhood characteristics										
GREEN			.028	(.008)	.029	(.008)	.029	(.008)	.028	(.008)
COMRECR			.025	(.008)	.026	(.008)	.025	(.008)	.025	(.008)
COMGATE			.105	(.019)	.104	(.019)	.105	(.019)	.105	(.019)
XWATER			.066	(.012)	.067	(.012)	.066	(.012)	.066	(.012)
WFP_NE			.170	(.051)	.166	(.051)	.170	(.051)	.170	(.051)
WFP_MW			.304	(.046)	.301	(.046)	.304	(.046)	.304	(.046)
WFP_SO			.365	(.046)	.363	(.045)	.365	(.046)	.365	(.046)
WFP_CA			.324	(.187)	.316	(.187)	.324	(.187)	.325	(.187)
WFP_WE			.436	(.084)	.429	(.083)	.436	(.084)	.436	(.084)
XTR_MET			.121	(.014)	.120	(.014)	.121	(.014)	.121	(.014)
SHP_MET			.046	(.018)	.044	(.018)	.046	(.018)	.046	(.018)
BARCL			-.096	(.018)	-.095	(.018)	-.096	(.018)	-.096	(.018)
ABAN			-.154	(.022)	-.149	(.021)	-.154	(.022)	-.154	(.022)
BADROADS			-.031	(.008)	-.030	(.008)	-.031	(.008)	-.031	(.008)
COMCRIME			-.029	(.010)	-.026	(.010)	-.029	(.010)	-.029	(.010)
COMODOR			-.046	(.018)	-.043	(.018)	-.046	(.018)	-.046	(.018)
XSTNOISE			-.037	(.010)	-.034	(.010)	-.037	(.010)	-.037	(.010)
JNK_MET			-.100	(.020)	-.094	(.020)	-.100	(.020)	-.100	(.020)
JNK_NM			-.018*	(.031)	-.010*	(.031)	-.017*	(.031)	-.018*	(.031)
COM1			-.038	(.010)	-.037	(.010)	-.038	(.010)	-.038	(.010)
COM2			-.030*	(.021)	-.029*	(.021)	-.030*	(.021)	-.030*	(.021)
MB_MET			-.165	(.024)	-.162	(.024)	-.165	(.024)	-.165	(.024)
MB_NM			-.092	(.020)	-.091	(.020)	-.092	(.020)	-.093	(.020)
alternative indicators of physical inadequacy										
NEW_INAD					-.112	(.017)				
AHS_MOD							-.014*	(.022)		
AHS_SEV									.036*	(.036)
Adj. R^2	**.5044**		**.5320**		**.5335**		**.5320**		**.5320**	

standard errors in parentheses. *indicates a coefficient ***not*** significant at the .1 level.

Table 2. Likelihood Ratio tests of alternatives to house value models in Table 1

Dependent variable: natural logarithm of value of owner-occupied single family detached housing units

	Model 1 location indicators housing unit char.	Model 2 location indicators housing unit char. neighborhood char.	Model 3 location indicators housing unit char. neighborhood char. NEW_INAD	Model 4 location indicators housing unit char. neighborhood char. AHS_MOD	Model 5 location indicators housing unit char. neighborhood char. AHS_SEV
Test against alternative of a Box-Cox form with parameter λ					
estimate of λ	0.0089	0.0089	0.0078	0.0088	0.0090
χ^2 statistic	1.386	1.437	1.096	1.403	1.456
d.f.	1	1	1	1	1
p-value	.2391	.2306	.2952	.2362	.2275
Test against a model with fewer independent variables					
null hypothesis	constant only	Model 1	Model 2	Model 2	Model 2
χ^2 statistic	14,307.826	1,188.738	68.215	0.401	1.032
d.f.	31	23	1	1	1
p-value	<.0001	<.0001	<.0001	.5265	.3097

Table 3. Multifamily Rent: Box-Cox regression estimates

Dependent variable: rent paid by tenants in structures with 5 or more units, transformed by Box-Cox parameter λ

	Model 1		Model 2		Model 3		Model 4		Model 5	
λ	-.4291	(.0344)	-.3887	(.0334)	-.3872	(.0334)	-.3887	(.0334)	-.3885	(.0334)
Constant	2.1586	(.1368)	2.3230	(.1491)	2.3297	(.1497)	2.3230	(.1491)	2.3238	(.1491)
location indicators										
CENT_NE	.0328	(.0079)	.0308	(.0076)	.0312	(.0076)	.0308	(.0076)	.0308	(.0075)
CENT_MW	.0134	(.0037)	.0091	(.0034)	.0092	(.0034)	.0091	(.0034)	.0091	(.0034)
CENT_SO	.0127	(.0035)	.0116	(.0036)	.0118	(.0036)	.0116	(.0036)	.0116	(.0036)
CENT_CA	.0314	(.0076)	.0365	(.0087)	.0369	(.0088)	.0365	(.0087)	.0364	(.0087)
CENT_WE	.0160	(.0042)	.0157	(.0045)	.0158	(.0045)	.0157	(.0045)	.0157	(.0045)
BURB_NE	.0309	(.0075)	.0342	(.0082)	.0346	(.0083)	.0342	(.0082)	.0342	(.0082)
BURB_MW	.0134	(.0037)	.0106	(.0035)	.0107	(.0036)	.0106	(.0035)	.0106	(.0035)
BURB_SO	.0163	(.0042)	.0164	(.0044)	.0166	(.0044)	.0164	(.0044)	.0164	(.0044)
BURB_CA	.0329	(.0079)	.0409	(.0097)	.0413	(.0098)	.0409	(.0097)	.0409	(.0097)
BURB_WE	.0159	(.0042)	.0168	(.0047)	.0170	(.0047)	.0168	(.0047)	.0169	(.0047)
NMET_NE	.0210	(.0065)	.0208	(.0072)	.0214	(.0073)	.0208	(.0072)	.0209	(.0072)
NMET_MW	-.0016*	(.0027)	-.0045*	(.0035)	-.0046*	(.0035)	-.0045*	(.0035)	-.0047*	(.0035)
NMET_WE	.0044*	(.0035)	.0049*	(.0044)	.0047*	(.0044)	.0049*	(.0044)	.0047*	(.0044)
housing unit characteristics										
SIZEBF85	.0003*	(.0005)	.0009*	(.0007)	.0008*	(.0007)	.0009*	(.0007)	.0008*	(.0007)
SIZE1985	.0010*	(.0009)	.0013*	(.0011)	.0013*	(.0011)	.0013*	(.0011)	.0014*	(.0011)
SIZEPOST	.0034	(.0011)	.0036	(.0012)	.0036	(.0012)	.0036	(.0012)	.0036	(.0012)
BATHS	.0069	(.0019)	.0076	(.0021)	.0077	(.0021)	.0076	(.0021)	.0078	(.0021)
HALFB	.0015*	(.0008)	.0023	(.0011)	.0023	(.0011)	.0023	(.0011)	.0023	(.0011)
BEDRMS	.0042	(.0011)	.0071	(.0017)	.0072	(.0017)	.0071	(.0017)	.0071	(.0017)
OTHROOMS	.0003*	(.0006)	.0006*	(.0007)	.0006*	(.0008)	.0006*	(.0007)	.0006*	(.0007)
GARAGEX	.0050	(.0014)	.0043	(.0014)	.0043	(.0014)	.0043	(.0014)	.0042	(.0014)
FIREPLAC	.0018*	(.0010)	.0038	(.0015)	.0039	(.0015)	.0038	(.0015)	.0038	(.0015)
UDISH	.0057	(.0015)	.0056	(.0016)	.0056	(.0016)	.0056	(.0016)	.0057	(.0016)
UDRY	.0049	(.0014)	.0059	(.0016)	.0059	(.0016)	.0059	(.0016)	.0058	(.0016)
building/neighborhood characteristics										
UELEV			.0043	(.0019)	.0044	(.0019)	.0043	(.0019)	.0044	(.0019)
UACCESSB			.0026	(.0011)	.0026	(.0011)	.0026	(.0011)	.0026	(.0011)
FLOOR_3			.0038	(.0012)	.0039	(.0012)	.0038	(.0012)	.0038	(.0012)
FLOOR_49			.0104	(.0029)	.0106	(.0029)	.0104	(.0029)	.0104	(.0029)
FLOOR_10			.0247	(.0063)	.0250	(.0064)	.0247	(.0063)	.0248	(.0063)
FIFTY_1			.0395	(.0120)	.0397	(.0121)	.0395	(.0120)	.0397	(.0120)
COMRECR			.0024	(.0010)	.0024	(.0010)	.0024	(.0010)	.0024	(.0010)
XWATER			.0032	(.0013)	.0032	(.0013)	.0032	(.0013)	.0032	(.0013)
XWFPROP			.0048	(.0027)	.0048	(.0028)	.0048	(.0027)	.0048	(.0027)
XTRAN			.0028	(.0012)	.0028	(.0012)	.0028	(.0012)	.0027	(.0012)
XSHOP			.0050	(.0023)	.0050	(.0023)	.0050	(.0023)	.0050	(.0023)
JNK_MET			-.0013*	(.0012)	-.0011*	(.0012)	-.0013*	(.0012)	-.0014*	(.0012)
JNK_NM			-.0110	(.0049)	-.0107	(.0049)	-.0110	(.0049)	-.0109	(.0049)
alternative indicators of physical inadequacy										
NEW_INAD					-.0030	(.0017)				
AHS_MOD							.00002*	(.0014)		
AHS_SEV									.0044*	(.0029)
Amemiya's PC	**.6179**		**.5531**		**.5527**		**.5535**		**.5530**	

standard errors in parentheses. *indicates a coefficient ***not*** significant at the .1 level.

Table 4. Likelihood Ratio tests of alternatives to the multifamily rent models in Table 3

Dependent variable: rent paid by tenants in structures with 5 or more units, transformed by Box-Cox parameter λ

	Model 1 location indicators housing unit char.	Model 2 location indicators housing unit char. building/community	Model 3 location indicators housing unit char. building/community NEW_INAD	Model 4 location indicators housing unit char. building/community AHS_MOD	Model 5 location indicators housing unit char. building/community AHS_SEV
Test against null of a linear model (λ=1)					
χ^2 statistic	2,210.051	2,228.667	2,226.896	2,228.496	2,230.078
d.f.	1	1	1	1	1
p-value	<.0001	<.0001	<.0001	<.0001	<.0001
Test against null of a semi-logarithmic model (λ=0)					
χ^2 statistic	167.435	145.452	144.488	145.448	145.470
d.f.	1	1	1	1	1
p-value	<.0001	<.0001	<.0001	<.0001	<.0001
Test against a model with fewer independent variables					
null hypothesis	constant only	Model 1	Model 2	Model 2	Model 2
χ^2 statistic	1,323.449	317.750	373.347	0.0002	2.553
d.f.	24	13	1	1	1
p-value	<.0001	<.0001	<.0001	.9902	.1101

Table 5. Number of Housing Units Classified as Inadequate Under Alternative Definitions

	Occupied		Non-Seasonal Vacant		Total
	Single-Family	Multifamily	Single-Family	Multifamily	
AHS severely	991,358	744,606	0	0	1,735,965
inadequate	1.3%	2.9%	0.0%	0.0%	1.5%
AHS moderately or	2,727,494	2,607,392	0	0	5,334,886
severely inadequate	3.5%	10.1%	0.0%	0.0%	4.6%
Inadequate under	6,733,007	2,153,890	1,104,633	397,619	10,389,149
new definition	8.5%	8.3%	19.4%	8.9%	9.0%
Total housing units	79,133,307	25,920,344	5,707,567	4,449,398	115,210,615

Table 6. Housing Units by Year Built

	Occupied		Non-Seasonal Vacant		Total
	Single-Family	Multifamily	Single-Family	Multifamily	
A. Units inadequate under new definition					
Built before 1940	2,073,311	711,765	477,613	185,514	3,448,204
	30.8%	33.1%	43.2%	46.7%	33.2%
Built 1940 to 1949	688,909	150,805	127,836	28,666	996,217
	10.2%	7.0%	11.6%	7.2%	9.6%
Built 1950 to 1959	935,887	157,986	165,810	49,159	1,308,842
	13.9%	7.3%	15.0%	12.4%	12.6%
Built 1960 to 1969	803,426	270,471	99,785	27,372	1,201,054
	11.9%	12.6%	9.0%	6.9%	11.6%
Built 1970 to 1979	1,069,371	521,169	142,209	63,983	1,796,733
	15.9%	24.2%	12.9%	16.1%	17.3%
Built 1980 to 1989	516,269	178,954	39,629	19,637	754,489
	7.7%	8.3%	3.6%	4.9%	7.3%
Built 1990 to 1999	380,763	90,624	15,802	10,095	497,284
	5.7%	4.2%	1.4%	2.5%	4.8%
Built 2000 to 2004	178,932	47,066	15,290	2,771	244,059
	2.7%	2.2%	1.4%	0.7%	2.3%
Built 2005 or later	86,137	25,050	20,659	10,422	142,268
	1.3%	1.2%	1.9%	2.6%	1.4%
Total	6,733,007	2,153,890	1,104,633	397,619	10,389,149
B. All units					
Built before 1940	12,078,056	4,756,872	1,295,838	957,960	19,088,726
	15.3%	18.4%	22.7%	21.5%	16.6%
Built 1940 to 1949	5,410,738	1,284,757	521,825	221,246	7,438,567
	6.8%	5.0%	9.1%	5.0%	6.5%
Built 1950 to 1959	10,045,797	1,678,732	686,503	206,774	12,617,806
	12.7%	6.5%	12.0%	4.7%	11.0%
Built 1960 to 1969	9,705,514	3,231,039	572,304	456,795	13,965,651
	12.3%	12.5%	10.0%	10.3%	12.1%
Built 1970 to 1979	13,150,016	6,619,579	742,667	1,052,086	21,564,348
	16.6%	25.5%	13.0%	23.7%	18.7%
Built 1980 to 1989	8,642,609	4,034,224	405,514	674,840	13,757,187
	10.9%	15.6%	7.1%	15.2%	11.9%
Built 1990 to 1999	9,449,565	2,112,683	478,721	346,680	12,387,649
	11.9%	8.2%	8.4%	7.8%	10.8%
Built 2000 to 2004	6,044,946	1,296,530	350,801	182,769	7,875,046
	7.6%	5.0%	6.2%	4.1%	6.8%
Built 2005 or later	4,606,067	905,928	653,394	350,246	6,515,635
	5.8%	3.5%	11.5%	7.9%	5.7%
Total	79,133,307	25,920,344	5,707,567	4,449,398	115,210,615

Table 7. Housing Units by Geography

	Occupied		Non-Seasonal Vacant		Total
	Single-Family	Multifamily	Single-Family	Multifamily	
A. Units inadequate under new definition					
Central City	1,930,735	1,315,266	376,062	267,035	3,889,098
	28.7%	61.1%	34.0%	67.2%	37.4%
Urban Suburb	1,860,964	526,729	205,822	78,455	2,671,969
	27.6%	24.5%	18.6%	19.7%	25.7%
Rural Suburb	932,336	55,413	143,889	9,666	1,141,304
	13.9%	2.6%	13.0%	2.4%	11.0%
Urban NonMetro	673,566	187,674	126,685	30,723	1,018,647
	10.0%	8.7%	11.5%	7.7%	9.8%
Rural NonMetro	1,335,406	68,809	252,176	11,740	1,668,131
	19.8%	3.2%	22.8%	3.0%	16.1%
Total	6,733,007	2,153,890	1,104,633	397,619	10,389,149
B. All units					
Central City	18,976,616	13,079,571	1,521,548	2,436,767	36,014,503
	24.0%	50.5%	26.7%	54.8%	31.3%
Urban Suburb	28,624,659	8,933,583	1,686,688	1,290,695	40,535,626
	36.2%	34.5%	29.6%	29.0%	35.2%
Rural Suburb	12,914,932	1,118,746	822,732	211,028	15,067,438
	16.3%	4.3%	14.4%	4.7%	13.1%
Urban NonMetro	6,041,805	2,015,375	554,617	364,156	8,975,953
	7.6%	7.8%	9.7%	8.2%	7.8%
Rural NonMetro	12,575,294	773,070	1,121,982	146,750	14,617,096
	15.9%	3.0%	19.7%	3.3%	12.7%
Total	79,133,307	25,920,344	5,707,567	4,449,398	115,210,615

Table 8. Housing Cost Burden for Households in Units Classified as Inadequate Under the New Definition

	Owner Occupied			Renter Occupied			Total
Household Income	Under 30% of Income	30-50% of Income	50% of Income or More	Under 30% of Income	30-50% of Income	50% of Income or More	
Under 30% AMI	769,197	38,605	106,118	1,165,377	55,057	231,845	2,366,200
30 to 50% AMI	762,509	2,508	0	805,814	0	0	1,570,831
50 to 80% AMI	976,511	0	0	752,663	0	0	1,729,174
80 to 120% AMI	1,100,113	0	0	428,960	0	0	1,529,074
120% AMI or more	1,421,420	0	0	270,198	0	0	1,691,618
Total	5,029,751	41,113	106,118	3,423,013	55,057	231,845	8,886,897

AMI=Area Median Income

Table 9.
Race/Ethnicity of Household Head in Units Classified as Inadequate Under the New Definition

	Owners		Renters	
	In Inadequate Units	All Owners	In Inadequate Units	All Renters
Non-Hispanic white	3,958,482	55,669,648	2,040,241	18,456,583
	76.5%	78.3%	55.0%	54.3%
Non-Hispanic black	582,333	5,941,607	768,626	7,067,630
	11.3%	8.4%	20.7%	20.8%
Hispanic	424,317	5,952,846	692,640	6,067,802
	8.2%	8.4%	18.7%	17.9%
Other	211,850	3,514,626	208,407	2,382,910
	4.1%	4.9%	5.6%	7.0%
Total	5,176,982	71,078,727	3,709,915	33,974,924

Table 10. Type of Household in Units Classified as Inadequate Under the New Definition

	Owners		Renters	
	In Inadequate Units	All Owners	In Inadequate Units	All Renters
Married couple	1,433,851	19,536,247	592,948	4,827,748
with children	27.7%	27.5%	16.0%	14.2%
Other	600,449	4,746,176	967,907	6,701,880
with children	11.6%	6.7%	26.1%	19.7%
65+ householder	851,531	16,514,343	273,081	4,336,733
with no children	16.5%	23.2%	7.4%	12.8%
Other	2,291,152	30,281,960	1,875,980	18,108,562
without children	44.3%	42.6%	50.6%	53.3%
Total	5,176,982	71,078,727	3,709,915	33,974,924

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