



Published in final edited form as:

*Epidemiology*. 2016 July ; 27(4): 518–524. doi:10.1097/EDE.0000000000000470.

## Property Values as a Measure of Neighborhoods:

### An Application of Hedonic Price Theory

Tammy Leonard<sup>a</sup>, Tiffany M. Powell-Wiley<sup>b,c</sup>, Colby Ayers<sup>d</sup>, James C. Murdoch<sup>a</sup>, Wenyan Yin<sup>a</sup>, and Sandi L. Pruitt<sup>e,f</sup>

<sup>a</sup>Economics Department, University of Dallas, Irving, TX

<sup>b</sup>Cardiovascular and Pulmonary Branch, National Heart, Lung, and Blood Institutes, National Institutes of Health, Bethesda, MD

<sup>c</sup>Applied Research Program, Division of Cancer Control and Population Sciences, National Cancer Institute, Rockville, MD

<sup>d</sup>Division of Cardiology, Department of Medicine, University of Texas Southwestern Medical Center, Dallas, TX

<sup>e</sup>Department of Clinical Sciences, University of Texas Southwestern Medical Center, Dallas, TX

<sup>f</sup>Harold C. Simmons Comprehensive Cancer Center, Dallas, TX

### Abstract

**Background**—Researchers measuring relationships between neighborhoods and health have begun using property appraisal data as a source of information about neighborhoods. Economists have developed a rich tool kit to understand how neighborhood characteristics are quantified in appraisal values. This tool kit principally relies on hedonic (implicit) price models and has much to offer regarding the interpretation and operationalization of property appraisal data-derived neighborhood measures, which goes beyond the use of appraisal data as a measure of neighborhood socioeconomic status.

**Methods**—We develop a theoretically informed hedonic-based neighborhood measure using residuals of a hedonic price regression applied to appraisal data in a single metropolitan area. We describe its characteristics, reliability in different types of neighborhoods, and correlation with other neighborhood measures (i.e., raw neighborhood appraisal values, census block group poverty, and observed property characteristics). We examine the association between all neighborhood measures and body mass index.

**Results**—The hedonic-based neighborhood measure was correlated in the expected direction with block group poverty rate and observed property characteristics. The neighborhood measure and average raw neighborhood appraisal value, but not census block group poverty, were associated with individual body mass index.

---

Correspondence: Tammy Leonard, Economics Department, University of Dallas, 1845 E. Northgate Drive, Irving, TX 75062. TLeonard@udallas.edu.

Supplemental digital content is available through direct URL citations in the HTML and PDF versions of this article ([www.epidem.com](http://www.epidem.com)).

**Conclusion**—We draw theoretically consistent methodology from the economics literature on hedonic price models to demonstrate how to leverage the implicit valuation of neighborhoods contained in publicly available appraisal data. Consistent measurement and application of the hedonic-based neighborhood measures in epidemiology will improve understanding of the relationships between neighborhoods and health. Researchers should proceed with a careful use of appraisal values utilizing theoretically informed methods such as this one.

---

Property appraisal data represent a promising data source for understanding how neighborhood environments impact health, but there is limited clarity about which neighborhood attributes are measured by appraisal data and which are relevant to health. As a data source, they are versatile because they can be aggregated to an unlimited number and size of geographies and are publicly available at little or no cost annually for most metropolitan areas in many developed countries. However, there is limited clarity about which health-relevant constructs are being measured by appraisal data. Recent studies have reported inverse associations between property values and cardiometabolic risk factors,<sup>1</sup> self-rated health,<sup>2</sup> and obesity.<sup>3,4</sup> However, the construct measured by appraisal data is underdeveloped and inconsistent with economists' in-depth understanding of housing markets. Generally, appraisal data have been assumed to be an indicator of neighborhood socioeconomic status (SES), however, economists' understanding of housing markets, through which appraisal values arise, presents a more in-depth sense of the information contained within appraisal values.

Although appraisal values have been found to be correlated with self-reported perceptions characterizing obesogenic environments and attenuate the relationship between perceptions of the neighborhood environment and body mass index (BMI),<sup>4</sup> the lack of clarity regarding what appraisal values measure makes it difficult to fully understand the relationship between appraisal values and health outcomes. Most authors have attributed the relationship to the influence of neighborhoods on health; however, there are many potential confounders in this causal pathway such as wealth and the ability to obtain a home loan (to purchase in an expensive neighborhood), among others. In other literature, appraisal values have been robustly correlated with neighborhood SES,<sup>5</sup> school quality,<sup>6</sup> distance to a city center,<sup>7</sup> house size, proximity to parks,<sup>7</sup> neighborhood foreclosure activity,<sup>8</sup> and a variety of other features.

Hedonic price models which decompose a house's price into individual prices for the bundle of attributes that constitute the house (e.g., bedrooms, bathrooms, yard space, and location) are used by economists to understand the relationship between neighborhoods and housing markets. These price models provide a foundation for understanding what we can infer about neighborhood characteristics based on observed appraisal data, including for example, is the neighborhood of high or low quality and is the inference obtained from a hedonic regression in one location comparable with those obtained in other areas. Hedonic price models offer tools that will allow health researchers to move beyond a simplified understanding of the information contained within appraisal values and use both self-reported and observed neighborhood characteristics alongside appraisal values to improve the understanding of the relationship between neighborhoods and health. The purpose of this article is to develop and apply a methodology for using appraisal values as a measure of neighborhood condition that

is theoretically consistent with modern hedonic price models. In doing so, we elucidate the advantages and limitations of using appraisal data to examine the relationship between neighborhoods and health.

## How Are Appraisal Data Created?

Different appraisal techniques are used for single-family residences and apartments.<sup>9</sup> Single-family residence appraisals are based on the sale price of similar nearby homes. Neighborhoods with little or no housing market activity may have appraisal values that do not reflect current conditions. In addition, in some jurisdictions, laws limit annual increases in appraisal values, thus appraisal values may lag neighborhood changes.<sup>10</sup> Apartment appraisals represent the present value of the property's predicted income cash flow based on rents and vacancy rates, for which annual data are readily available.<sup>9</sup> Importantly, because of the different methods for estimating appraisal values, combining single-family residence and apartment appraisal data to create a single measure of neighborhood condition is inappropriate and could produce biased results.

## What Do Appraisal Data Measure?

Hedonic price models decompose a house's price into separate prices for each individual housing attribute.<sup>11-17</sup> Economists refer to individual attribute prices as "hedonic," "implicit," or "marginal" prices. The *hedonic* price of a square foot of living area represents the *implicit* amount of money that an average consumer in the local housing market is willing to pay for an additional (e.g., *marginal*) square foot of living area. In other words, it is the average amount by which you would expect your home value to increase if you added an additional square foot of living space.

Hedonic price models are a "gold standard" means of assessing market prices of nonmarket goods, which are not explicitly bought and sold individually.<sup>11-14,16-24</sup> Nonmarket goods include clean air, nice views, and quality neighborhoods. They are bought indirectly through housing because geography is an attribute of the housing bundle.

Considering the conceptual model of neighborhoods and health presented by Diez Roux and Mair,<sup>25</sup> hedonic models may be used to estimate the hedonic price of attributes in neighborhood physical and social environments. However, property values reflect the average value that the *local* market associates with different housing attributes. Thus, neighborhood characteristics most reflected in home prices have been shown to vary across metropolitan areas. In Columbus, Ohio, physical disorder (graffiti, trash, unkempt lawns, abandoned buildings, poor public areas, and busy streets) was capitalized into home prices.<sup>26</sup> In Baltimore, MD, neighborhood racial composition and SES were more strongly related to house prices than were neighborhood crime or educational quality of local school districts.<sup>27</sup> Using a nationally representative sample, other authors identified race as a key variable reflected in house price only in specific subsamples (owner-occupied houses outside of the western US and rental-occupied housing).<sup>28</sup> Readers wishing to use appraisal data to measure neighborhoods would benefit from a review of the hedonic price literature for the specific metropolitan area of interest. This literature can be found by searching key urban

economics journals (i.e., Journal of Urban Economics, Regional Science and Urban Economics, Real Estate Economics) or through Google Scholar searches using search terms “hedonic models housing markets CITY” where “city” should be replaced with the location of interest.

## Extracting a Measure of Neighborhood Condition from Appraisal Data

To generate an unbiased measure of neighborhood condition, we separate the hedonic price of neighborhood condition from the hedonic price of other housing attributes by estimating a hedonic price model that includes all observable variables *except* neighborhood condition. Our proposed hedonic-based neighborhood measure (*HBNM*) takes on the values of the residuals from the estimated hedonic model. Residuals, the combined hedonic price of any attributes not explicitly included in the hedonic model, are calculated as the difference between the actual appraisal value and the hedonic model’s predicted appraisal value.<sup>29,30</sup> The *HBNM*’s grounding in hedonic price theory distinguishes it from previous appraisal-based neighborhood measures. See eAppendix A (<http://links.lww.com/EDE/B29>) for a detailed discussion and comparison to alternative appraisal-based measures in the literature.

One of the advantages of the *HBNM* is its flexibility. Since this measure is derived from the residuals of a hedonic regression, it provides a more (less) specific measure of neighborhood condition if more (fewer) neighborhood-level characteristics are included in the first stage regression. In addition, the precision with which covariates in the first stage regression are measured will impact the precision with which the *HBNM* is able to measure neighborhood condition. For example, if environmental quality is included as a covariate in the hedonic regression, then it measures neighborhood condition *independent of* environmental quality; but if the included measure of environmental quality is imprecisely measured, then the *HBNM* will also have less precision. Furthermore, if the measurement error in environmental quality is correlated with neighborhood condition, then *HBNM* will be biased.

It is rarely the case that data will be available to control for *everything* in the hedonic model. Any factors unrelated to neighborhood condition that remain in the residuals are “nuisance” variables. A complete statistical exposition of how the *HBNM* is affected by “nuisance” variables is provided in eAppendix B (<http://links.lww.com/EDE/B29>). To assess the validity of the measure, “nuisance” variables and their expected correlation with neighborhood condition should be assessed. If “nuisance” variables are uncorrelated with neighborhood condition, then they will operate as a random disturbance (i.e., decreasing *HBNM*’s precision but not producing bias). However, if “nuisance” variables are correlated with neighborhood condition such that they are more/less likely to increase home prices in neighborhoods where condition is better, *HBNM* will be biased. The bias will be upward if the correlation is positive and downward otherwise. Because “nuisance” variables will vary both temporally and across housing markets, identification and thoughtful discussion of nuisance variables and their potential for bias should be a standard component of the methodological description of any work using the *HBNM*.

Obtaining data to construct a well-specified first stage regression model is essential. Many covariates can be obtained from the tax assessor's office and are often provided with the appraisal data (e.g., house characteristics and taxing jurisdictions including school districts, hospital districts, and cities). Other covariates can be obtained from merging with increasingly available geo-referenced datasets (e.g., distance to city center).

The *HBNM* may be constructed in different ways depending on the intended purpose. Herein, we consider a common definition for neighborhood condition that we use it to measure: "overall quality of the observed neighborhood environment." Using this definition, Table 1 provides a list of some likely "nuisance" variables: variables that the researcher would like to include in the first stage regression model but is not able to observe.

The first group of nuisance variables includes local housing and labor market features. Perceived future price trajectories are problematic when *anticipated* changes in neighborhoods result in elevated neighborhood prices that are not related to *current* neighborhood conditions. Labor market shocks include the opening or closure of a large factory or office complex, whereas housing market shocks include foreclosures, siting of new neighborhood amenities/disamenities, or zoning changes. Both are problematic if they impact home prices independent of their impact on the neighborhood itself. When considering longitudinal analysis, shocks affecting the entire geographic area are a particular concern because they could affect temporal comparisons. However cross-sectional variation in neighborhood measures will remain consistent if the shocks affect the entire market equally. Researchers may consider creating categorical values of *HBNM* based on time-consistent variation and then use these categorical measures to analyze temporal changes. Housing and labor market shocks are likely uncorrelated with the local neighborhood condition.

If researchers wish to use *HBNM* to measure a specific neighborhood characteristic, then other neighborhood features should be considered "nuisance" variables. These nuisance variables are likely to be positively correlated with neighborhood condition. For example, neighborhood reputation is likely worse in neighborhoods with poorer condition; and pollution is less likely in better neighborhoods.

Finally, there are other geographic and jurisdictional "nuisance" variables that may lead to biased measures of neighborhood condition, but which could be controlled for in the hedonic model using geographic information system (GIS)-derived measures, such as regional fixed effects. These include school quality,<sup>31</sup> ease of access to employment or retail centers,<sup>7</sup> and other jurisdictional features such as different property tax rates,<sup>32</sup> and city or health care services.<sup>33</sup>

Researchers should think critically about potential "nuisance" variables omitted from the hedonic model and seek alternative data sources (e.g., days on market trends, news reports, etc.) and methods (GIS-derived measures) to assess their impact.

## ***HBNM* as a Measure of Neighborhood at Different Levels**

The *HBNM* is calculated for every housing parcel; therefore, *HBNM* takes on a *unique* value at *every* parcel. We refer to this as the “parcel-level” value of *HBNM*. However, because it is calculated using all model data, the parcel-level value of *HBNM* reflects the condition of the housing parcel associated with it, the condition of other parcels in the neighborhood, and other relevant environmental factors, including public facilities, parks/greenspace, and institutions.

Parcel-level values of *HBNM* may be aggregated to create a “neighborhood-level” *HBNM*. The neighborhood-level measure reflects the average observed condition of the neighborhood, whereas the parcel-level measure allows for differentiation among parcels within a single neighborhood. For example, within residential neighborhoods, it is not uncommon to see a well-maintained home adjacent to a poorly maintained home. Parcel-level *HBNM* for the well-maintained home should be higher than for the poorly maintained home because all other “neighborhood” elements captured by the parcel-level *HBNM* for the two homes should be equal; but each individual home’s property upkeep will cause the parcel-level *HBNMs* to differ across the two adjacent homes.

## **METHODS**

### **Housing Data**

Appraisal data (appraisal value, home characteristics, and parcel location) for Dallas County, TX (2009), are publicly available and were obtained from the Dallas Central Appraisal District. 2005 and 2010 sales data (sale price and location) for Dallas County were obtained from the University of Texas at Dallas Real Estate Research Database. Appraisal and sales data are recorded for housing parcels, which consists of the house and surrounding yard and is the geographic unit used for assessing property taxes.

### **Neighborhood Data**

Median block group household income and poverty rates were obtained from the American Community Survey 2006 to 2010 5-year estimates.

Neighborhood observational data for each housing parcel were recorded by trained field observers for the Fair Park Neighborhood Study from September 4, 2010 to January 28, 2011.<sup>34</sup> Field observers documented peeling paint, broken windows, boards/bars on windows/doors, lawn upkeep, fence quality, trash, and land use for every single-family residence (n=6,449) in the neighborhood and the associated variables were coded as either 1 (condition present) or 0 (not present). The Fair Park neighborhood in Dallas, TX, consisting of 32 census block groups within seven census tracts, is very low income (median household income \$19,939) and predominantly African American (70%) and Hispanic (26%).<sup>35</sup> Further details regarding Fair Park study data collection are presented elsewhere.<sup>34</sup>

Institutional review board approval was not required for American Community Survey and Fair Park neighborhood data.

## Individual Data

Individual health outcome data (BMI) come from the Dallas Heart Study (DHS) described in detail in Appendix D (<http://links.lww.com/EDE/B29>) and elsewhere.<sup>36</sup> The DHS protocol was approved by the institutional review boards at the University of Texas Southwestern Medical Center and the National Heart, Lung, and Blood Institute.

## Statistical Analysis

Using housing appraisal and sales transactions data (2005 and 2010) from Dallas County, TX, we examined the availability of appraisal data and market real-estate transactions for single-family residence and multi-family properties at different geographic buffer sizes and in different median block group income strata.

Next, we calculated *HBNM*. To calculate *HBNM*, we estimated a hedonic model defined for all single-family residences in Dallas County, TX. Natural log of appraisal value was the dependent variable and the following housing characteristics were included as model covariates: indicator variables for school district and city jurisdiction in which the property is located, house age and age squared, condition of the house structure as assessed by the appraisal district using an eight-point scale ranging from unsound to excellent, square feet of living area, number of stories, type of foundation (e.g., slab, pier and beam, post, or block), type of fence (e.g., stone, wood, iron, brick, chain, and none), presence of central air condition-of a swimming pool. Parcel-level *HBNM* was calculated as the difference between the actual appraisal value and the value predicted from the regression model. Parcel-level *HBNM* values within the same block group were averaged to create the block-group neighborhood-level *HBNM*, and parcel-level *HBNM* values within a half-mile radius of DHS participants' homes were averaged to create the "half-mile buffer" neighborhood-level *HBNM*. *HBNM* as defined here measures the neighborhood condition that would be experienced by a potential homebuyer. It includes observable features that would be noticed during the housing search. For example, neighborhood upkeep, aesthetics, and any perceptions about the neighborhood (e.g., this is a "good" neighborhood to raise a family in, or this is a "hip, up and coming" neighborhood). In contrast, raw appraisal values would also measure these factors; however, they would also be confounded by the covariates included in the first stage regression.

To assess the ability of *HBNM* to distinguish between parcels in the same neighborhood but of different external condition, we estimated  $\chi^2$  statistics to test the correspondence between observed undesirable parcel features and whether or not the parcel-level *HBNM* was above or below the neighborhood mean *HBNM*. We expect that higher parcel-level *HBNM* values should be associated with fewer undesirable parcel features.

Next, we assessed the performance of block group neighborhood-level *HBNM* by comparing with census block group poverty. We calculated Pearson correlation coefficients for block-group neighborhood-level *HBNM* and block group poverty rates.

Finally, we estimated multivariate mixed models with census block group random effects using individual data from the DHS. The continuous dependent variable was BMI and in subsequent models the primary independent variable was the average single-family

residence appraisal value within a half-mile buffer, the “half-mile buffer” neighborhood level *HBNM*, and census block group poverty.

## RESULTS

### Spatial Distribution of Housing Units and Housing Market Activity

We analyzed the level of housing market activity and the presence of apartments in different neighborhood sizes to understand data reliability across different geographies, in different neighborhoods, and its sensitivity to temporal trends. In some cases, the real estate market may not have enough activity or have an uneven distribution of housing units to support a reliable *HBNM*. Full results are in eAppendix C (<http://links.lww.com/EDE/B29>). Although there were 55% fewer sales in 2005 compared with 2010, many parcels did not have a sale within the ¼ mile buffer for either 2005 or 2010. If ¼ mile buffer size is used in analysis, annual property appraisal data are not necessarily an annual measure of neighborhood condition. Furthermore, results will be biased if the *HBNM* is applied to multiple neighborhoods where the level of housing market activity varies substantially across neighborhoods. Apartments are scarce in Dallas County: 50% (low income) to 72% (high income) parcels did not have an apartment within ¼ mile.

### Parcel-level *HBNM* and Observed Housing Characteristics in the Fair Park Neighborhood

Table 2 presents  $\chi^2$  values for correspondence between parcel-level values of *HBNM* that are above/below the mean and the presence of undesirable housing characteristics. Existence of peeling paint, broken windows, boards on windows, bars on windows or doors, lawn maintenance, and fence condition all have statistically significant  $\chi^2$  statistics. Each of these undesirable housing characteristics are more predominant on houses with below average *HBNM*.

### Neighborhood-level *HBNM* Correspondence with Block Group Poverty

Higher values of *HBNM* represent better neighborhoods, whereas lower values of block group poverty are associated with better neighborhoods. Block group values of the two measures are correlated ( $-0.2510$ , 95% confidence interval,  $-0.253$ ,  $-0.249$ ) as expected. This indicates that when poverty is higher, then *HBNM* is also likely to indicate a poorer neighborhood condition.

### Association with BMI in the Dallas Heart Study

Both average *HBNM* and average single-family residence appraisal values within a half-mile radius of DHS participant’s home address, but not block group poverty, were associated with BMI (eTable D.2; <http://links.lww.com/EDE/B29>). The estimated effect size of a half-standard deviation change in neighborhood measure was greater for *HBNM* than for raw appraisal data. Full results tables are provided in eAppendix D (<http://links.lww.com/EDE/B29>).



## DISCUSSION

This study presented the hedonic-based neighborhood measure as a method for using appraisal data to measure neighborhood conditions that allows for careful consideration of what is being measured by appraisal data. Table 3 provides an overview of key considerations for researchers considering the measure. This measure will likely vary across housing markets. Researchers may standardize the measure within a single housing market, so that data from multiple markets may be integrated. However, the source of variation in the standardized hedonic-based neighborhood measure may differ across markets (i.e., palm trees may be highly valued in Florida and snow-plowed routes may be highly valued in Michigan). Furthermore, measurement error in *HBNM* associated with low housing market activity, limited availability of variables for the first stage regression, or validity of appraisal data should be considered.

The hedonic-based neighborhood measure exhibits convergent validity at both the parcel and neighborhood level. When comparing parcel-level *HBNM* to observed parcel characteristics, *HBNM* was associated with six of the seven parcel attributes examined. The exception was trash in the yard or curb. Trash may not be captured by the hedonic-based measure because, when purchasing a home, potential buyers may not consider trash because it is easily removed. We also found that neighborhood-level *HBNM* was correlated with, but distinct from, census block group poverty level. Hedonic-based neighborhood measure is distinct from poverty measures in that it directly measures the physical neighborhood condition as evaluated by prospective home buyers, whereas poverty, a characteristic of the neighborhood residents, is merely correlated with neighborhood physical condition.

Neighborhood-level *HBNM* was associated with individual BMI. The estimated relationship had a slightly higher effect size than the similarly estimated relationship between average neighborhood appraisal values and BMI, whereas the relationship between neighborhood poverty levels and BMI was not significant. These results suggest that the constructs measured by appraisal values go beyond those contained in SES measures, such as neighborhood poverty levels. This illustrates the need to gain a deeper understanding of the constructs measured by appraisal data so that results may be more readily interpreted.

There are limitations to our study. First, we examined a single housing market. The density and structure of housing differs substantially across metropolitan areas. Also, we examined the relationship between parcel-level *HBNM* and observational neighborhood data only within one low income, predominantly minority neighborhood. The hedonic-based neighborhood measure may measure other aspects of neighborhood in different areas, and it may be better at identifying variation in neighborhood characteristics when used over a larger geographic area with more neighborhood heterogeneity. Finally, the application of methods discussed here to rural housing markets is outside the scope of this article.

Generalizability of our results in terms of validation of the hedonic-based neighborhood measure is limited for the reasons cited above. However, the method for creating the measure and the considerations that should be taken when interpreting appraisal-based measures are highly generalizable because they are grounded in rich economics literature

that spans diverse housing markets. In particular, the measure takes into account the statistical methods used to calculate appraisal values,<sup>9</sup> the foundations for understanding implicit prices,<sup>14</sup> and recent advances toward capitalizing geographic attributes into home prices.<sup>13</sup>

In the public health literature, existing methods fail to acknowledge the richness of the information contained within appraisal values and the complexity of urban housing markets that give rise to appraisal values. As a result, none of the published statements in the public health literature regarding the nature of neighborhood information contained in appraisal data seems fully accurate. Average neighborhood appraisal values are not a “neighborhood wealth metric”<sup>2</sup> because (1) housing is a large, but not the only, component of household wealth<sup>37</sup>; (2) some neighborhood residents may rent—appraisal values would be related to income rather than wealth for these residents; and (3) many home owners have small equity stakes, so in fact an inverse relationship between net-wealth and appraisal values may exist.<sup>38–40</sup> Average neighborhood appraisal values are also not “an objective spatially informed SES measure.”<sup>1</sup> Hedonic models indicate that neighborhood characteristics reflected in appraisal prices are those valued by local housing market participants; they are local residents’ mean subjective valuation of neighborhood conditions. Features of neighborhoods valued in some neighborhoods may not be valued elsewhere. Relatedly, housing appraisal values do not provide “a novel measure of SES at the individual level.”<sup>3</sup> Appraisal data are not necessarily reflective of the individual property owner/occupier’s SES, although they have been shown to be correlated with neighborhood SES.<sup>5</sup> In short, appraisal values can be beneficial to our understanding of the relationships between neighborhoods and health, but what they measure should be carefully considered in future research. The hedonic-based neighborhood measure provides a method for health researchers to more accurately leverage and utilize appraisal data as a new measure of neighborhood condition with a more robust understanding of what is being measured. Further study evaluating the relationship between hedonic price methods to measure neighborhoods and health outcomes will provide additional clarity regarding what is being measured in appraisal values that is most relevant to health.

## Acknowledgments

We are grateful for the helpful comments of Dr. Mario Schootman, Dr. Christy Hoehner, and Dr. David Berrigan.

This study was supported by the National Science Foundation (NSF/SES-0827350). Funding support for Dr. Powell-Wiley is provided by the Division of Intramural Research of the National Heart, Lung, and Blood Institute at the National Institutes of Health.

## References

1. Coffee NT, Lockwood T, Hugo G, Paquet C, Howard NJ, Daniel M. Relative residential property value as a socio-economic status indicator for health research. *Int J Health Geogr.* 2013; 12:22. [PubMed: 23587373]
2. Moudon AV, Cook AJ, Ulmer J, Hurvitz PM, Drewnowski A. A neighborhood wealth metric for use in health studies. *Am J Prev Med.* 2011; 41:88–97. [PubMed: 21665069]
3. Rehm CD, Moudon AV, Hurvitz PM, Drewnowski A. Residential property values are associated with obesity among women in King County, WA, USA. *Soc Sci Med.* 2012; 75:491–495. [PubMed: 22591823]

4. Drewnowski A, Aggarwal A, Rehm CD, Cohen-Cline H, Hurvitz PM, Moudon AV. Environments perceived as obesogenic have lower residential property values. *Am J Prev Med.* 2014; 47:260–274. [PubMed: 25049218]
5. Li MM, Brown HJ. Micro-neighborhood externalities and hedonic housing prices. *Land economics.* 1980:125–141.
6. Dhar P, Ross SL. School district quality and property values: examining differences along school district boundaries. *J Urban Econ.* 2012; 71:18–25.
7. McMillen DP. The return of centralization to Chicago: using repeat sales to identify changes in house price distance gradients. *Reg Sci Urban Econ.* 2003; 33:287–304.
8. Leonard T, Murdoch J. The neighborhood effects of foreclosure. *J Geogr Syst.* 2009; 11:317–332.
9. Pagourtzi E, Assimakopoulos V, Hatzichristos T, French N. Real estate appraisal: a review of valuation methods. *JPIF.* 2003; 21:383–401.
10. Brookshire DS, Thayer MA, Schulze WD, d'Arge RC. Valuing public goods: a comparison of survey and hedonic approaches. *Am Econ Rev.* 1982; 72:165–177.
11. Clapp JM, Nanda A, Ross SL. Which school attributes matter? The influence of school district performance and demographic composition on property values. *J Urban Econ.* 2008; 63:451–466.
12. Nguyen-Hoang P, Yinger J. The capitalization of school quality into house values: a review. *J Hous Econ.* 2011; 20:30–48.
13. Rosen S. Hedonic prices and implicit markets: product differentiation in pure competition. *J Polit Econ.* 1974; 82:34–55.
14. Sheppard, S. *Handbook of Regional and Urban Economics.* Vol. 3. Amsterdam: Elsevier; 1999. Hedonic analysis of housing markets; p. 1595–1635.
15. Small KA, Steimetz SSC. Spatial hedonics and the willingness to pay for residential amenities\*. *J Reg Sci.* 2012; 52:635–647.
16. Smith VK, Huang J-C. Can markets value air quality? A meta-analysis of hedonic property value models. *J Polit Econ.* 1995; 103:209–227.
17. Boyle MA, Kiel KA. A survey of house price hedonic studies of the impact of environmental externalities. *J Real Estate Lit.* 2001; 9:117–144.
18. Gibbons S. The costs of urban property crime. *Econ J.* 2004; 114:F441–F463.
19. Nelson JP. Meta-analysis of airport noise and hedonic property values. *JTEP.* 2004; 38:1–27.
20. Can A. The measurement of neighborhood dynamics in urban house prices. *Econ Geogr.* 1990; 66:254–272.
21. Can A. Specification and estimation of hedonic housing price models. *Reg Sci Urban Econ.* 1992; 22:453–474.
22. Follain JR, Jimenez E. Estimating the demand for housing characteristics: a survey and critique. *Reg Sci Urban Econ.* 1985; 15:77–107.
23. Bajari P, Fruehwirth JC, Kim KI, Timmins C. A rational expectations approach to hedonic price regressions with time-varying unobserved product attributes: the price of pollution. *Am Econ Rev.* 2012; 102:1898–1926.
24. Diez Roux AV, Mair C. Neighborhoods and health. *Ann N Y Acad Sci.* 2010; 1186:125–145. [PubMed: 20201871]
25. Seo W, von Rabenau B. Spatial impacts of microneighborhood physical disorder on property resale values in Columbus, Ohio. *J Urban Plan Dev.* 2010; 137:337–345.
26. Dubin RA, Sung C-H. Specification of hedonic regressions: non-nested tests on measures of neighborhood quality. *J Urban Econ.* 1990; 27:97–110.
27. Harris DR. “Property values drop when Blacks move in, because...”: racial and socioeconomic determinants of neighborhood desirability. *Am Soc Rev.* 1999:461–479.
28. Greene, WH. *Econometric Analysis.* 4. New York, NY: Macmillan; 2000.
29. Wooldridge, JM. *Econometric Analysis of Cross Section and Panel Data.* Cambridge, MA: The MIT Press; 2002.
30. Basu S, Thibodeau TG. Analysis of spatial autocorrelation in house prices. *J Real Estate Finance Econ.* 1998; 17:61–85.

31. Palmon O, Smith BA. New evidence on property tax capitalization. *J Polit Econ*. 1998; 106:1099–1111.
32. Bartholomew K, Ewing R. Hedonic price effects of pedestrian-and transit-oriented development. *J Plan Lit*. 2011; 26:18–34.
33. Leonard TC, Caughy MO, Mays JK, Murdoch JC. Systematic neighborhood observations at high spatial resolution: methodology and assessment of potential benefits. *PLoS One*. 2011; 6:e20225. [PubMed: 21673983]
34. US Census. [Accessed 5 January 2013] 2005–2009 ACS 5-year estimates. Available at: [http://www.census.gov/acs/www/data\\_documentation/2009\\_release/](http://www.census.gov/acs/www/data_documentation/2009_release/)
35. Victor RG, Haley RW, Willett DL, et al. Dallas Heart Study Investigators. The Dallas Heart Study: a population-based probability sample for the multidisciplinary study of ethnic differences in cardiovascular health. *Am J Cardiol*. 2004; 93:1473–1480. [PubMed: 15194016]
36. Leonard T, Di W. Is household wealth sustainable? An examination of asset poverty reentry after an exit. *J Fam Econ Issues*. 2013:1–14.
37. Bricker J, Kennickell AB, Moore KB, Sabelhaus J. Changes in US family finances from 2007 to 2010: evidence from the survey of consumer finances. *Federal Reserve Bulletin*. 2012; 98:80.
38. McKernan S-M, Ratcliffe C. Events that trigger poverty entries and exits. *Soc Sci Quart*. 2005; 86:1146–1169.
39. Rank, MR., Hirschl, TA. Center for Social Development Working Papers. Ann Arbor, MI: University of Michigan; 2010. Estimating the life course dynamics of asset poverty.

TABLE 1

## Nuisance Variables and Their Relationship with Overall Quality of the Observed Neighborhood Environment

Characteristic Not Observed by Researcher	Relationship with Neighborhood Condition	Type of Bias
Market features		
Perceived future neighborhood price trajectory	Uncorrelated	Random effect
Labor market shock <sup>*</sup>	Uncorrelated	Random effect
Housing market shock <sup>†</sup>	Uncorrelated	Random effect
Neighborhood features		
Neighborhood reputation	Positively correlated	Upward bias
Pollution	Negatively correlated	Downward bias
View	Positively correlated	Upward bias
Geographic/jurisdictional features		
School quality	Positively correlated	Upward bias
Ease of access to jobs/retail	Varies; depends on city geography	Varies
Other jurisdictional amenities (e.g., health care services, city services, etc)	Varies; location specific	Varies

<sup>\*</sup> Any unexpected event impacting labor markets is considered a labor market shock. Examples of labor market shocks include the closure of major employment centers, or a sharp increase in unemployment during economic recessions.

<sup>†</sup> Any unexpected event impacting housing markets is considered a housing market shock. Examples of housing market shocks include a rapid increase in housing demand generated by economic growth, and a similar decrease in housing prices related to an economic recession.

**TABLE 2**Difference in House Conditions for SFRs with High Versus Low *HBNM*<sup>a</sup>

House Characteristic	Low HBNM <sup>a</sup>	High HBNM <sup>a</sup>	$\chi^2$
	n (%)	n (%)	
House has peeling paint	2,487 (54)	2,089 (46)	175.270
No peeling paint	663 (36)	1,175 (64)	
House has broken windows	136 (58)	99 (42)	7.505
No broken windows	3,013 (49)	3,165 (51)	
House has boards on windows	461 (62)	279 (38)	58.339
No boards on windows	2,687 (48)	2,985 (53)	
House has bars on windows or doors	1,983 (49)	2,129 (52)	3.604
No bars on windows or doors	1,167 (51)	1,135 (49)	
Lawn is poorly maintained	549 (54)	468 (46)	11.474
Lawn is maintained	2,601 (48)	2,796 (52)	
Fence is in disrepair	312 (56)	250 (44)	10.086
Fence condition is o.k.	2,838 (49)	3,013 (52)	
Trash along curb or yard	114 (49)	113 (51)	0.1158
No trash along curb or yard	3,036 (49)	3,151 (51)	

<sup>a</sup>High (low) values of HBNM are expected to be associated with higher (lower) quality neighborhoods.

SFR indicates single-family residence; HBNM hedonic-based neighborhood measure.

**TABLE 3****The Hedonic-Based Neighborhood Measure (HBNM) at a Glance**

HBNM measures...	HBNM does <i>not</i> measure...
Average local neighborhood condition observed by potential homebuyers	Any covariates included in the first stage regression model
Considerations for use of the HBNM	
The HBNM reflects the mean subjective value of neighborhood attributes that can be observed by prospective homebuyers and is sensitive to the mean valuation of local housing market participants	
HBNM will measure neighborhood features differently in different housing markets	
Measurement error associated with the HBNM will be greater in neighborhoods with fewer market sales or when variables included in the first stage regression are measured with error	
Researchers may aggregate data to the buffer size that is theoretically most relevant to the research question. However, lack of housing market activity or scarcity of sfr (or apartment) properties may limit the resolution of the appraisal data used to measure neighborhoods as buffer size decreases	
HBNM should be constructed using appraisal data for only one type of property (i.e., single family residence or apartment)	
HBNM should only be used in jurisdictions where policies are in place to govern the integrity of appraisal data. In many cases, property appraisal data is the basis for assessing taxes, thus robust systems exist to ensure data integrity	