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House Prices and School Quality: Instruments, Signaling, Usage and Perceptions

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Abstract We identify commonly-available instrumental variables for housing hedonics for proficiency tests, school spending, and property taxes. We estimate the hedonic simultaneously with the reasons a person bought his house. We find larger housing value elasticities than previous studies: 0.47 for test scores, 1.07 for expenditures per pupil, and -0.37 for property taxes. We suggest schooling expenditures acts as a signaling mechanism. We find that people who use private schools and think their private school is excellent pay an additional 10% house price premium; this finding, along with capitalization of private school test scores, supports the theory of the marginal consumer.

Keywords Capitalization, House Price Hedonic, School Quality, Signaling, Theory of Marginal Consumer, Endogenous Sorting

JEL Classification: H42, I21, R21, R31

1. Introduction

Dozens of articles on the capitalization of public schooling services into house prices have been published even since 1999 (Nguyen-Hoang and Yinger [1]), showing that the topic is as relevant as ever, and that there is still widespread disagreement on the proper empirical technique to use. The current study contributes to the literature in five main ways. It (1) finds new instruments for proficiency test scores and property taxes; (2) estimates the house price hedonic in a system of equations that includes the public services that most attracted people to their houses; (3) addresses endogenous sorting by including individual buyer characteristics; (4) proposes that expenditures are capitalized into house prices not for their ability to enhance education but as a signaling mechanism; and (5) examines whether people's attitudes toward their nearest public and private schools—as well as their use of them—affect their bids for housing.

Valid instruments are hard to find, but the current study finds readily-available instruments that pass many diagnostic tests for instrument validity. The new instrument for proficiency tests is student discipline problems; for the property tax rate, it is the percent of property value from non-residential land use. The instruments pass a wide variety of diagnostic tests to support their validity, and they make a big difference in the estimates. Hilber and Mayer [2] inspire the use of population density to instrument for expenditures per pupil, which is an additional school quality measure.[i] Instrumenting for these three variables more than doubles the elasticity of each, so that we find the elasticity of house price with respect to proficiency tests is 0.47, and corresponding values for expenditures per pupil of 1.07 and property taxes of -0.37. Stated differently, a one standard deviation rise in proficiency test passage is associated with a 10.7% increase in constant-quality house price, with corresponding values of + 13.6% for expenditures and - 5.9% for property taxes . The school-related elasticities are much stronger than those reported in the literature, perhaps indicating downward bias in other studies.

When people buy a house, they must also choose the services that accrue to that house. Among the major services that accrue to a house are schooling, police, and environmental services, along with the taxes associated with them. We estimate our house price hedonic in a system of equations that models whether a person bought their house with taxes, police services, school quality, and environmental quality in mind. This is an important contribution to the literature because a Breusch-Pagan test rejects the null hypothesis that the equations in the system are independent, suggesting that it is appropriate to model a house price hedonic with the reasons a person bought his house when data permits. The current study also addresses the problem of endogenous sorting--also called residential sorting (Bayer, Ferreira, and McMillan [3])--in a new way: by including individual buyer characteristics in the hedonic. If the Bayer, Ferreira, and McMillan [3] solution is to include small-neighborhood demographics as control variables to capture preferences, then including individual buyer demographic characteristics may be even better, while not running into the "difficult problems of interpretation and specification" that Nguyen-Hoang and Yinger [1] point out.

We propose a theory that the capitalization of school expenditures into house price—holding proficiency passage

constant—indicates a signaling mechanism. We are not aware of any other study that suggests this signaling mechanism, but it does help solve an important puzzle in the literature. The weak empirical link between expenditures and school outcomes implies there must be another reason people vote for such high expenditures. Capitalization itself has been interpreted as a sign of productive inefficiency and allocative inefficiency. High levels of school spending can be outwardly visible, and data on spending is easy to find and understand, so voting for more school spending signals to prospective homebuyers that theirs is a community that puts a strong emphasis on public education.

We also fill a void in the literature by investigating whether people's attitudes toward school and their usage of schools is reflected in house prices. All else constant, we find that homebuyers who have children who attend public school do not pay a premium for their houses, holding constant school proficiency and expenditures. We do find, however, that homebuyers who both use private schools and think their nearest private school is excellent pay a 10% premium for their houses. Along with another finding, this suggests the theory of the marginal consumer may hold true for our sample of Ohio homebuyers.

2. Literature Review

The recent, abundant literature on the capitalization of school quality into house prices is well-summarized in Nguyen-Hoang and Yinger [1]. Importantly for the current study, the review article finds that both school outputs and school inputs (expenditures) are related to bids for housing. The body of research continues to grow, with Vandegrift and Lockshiss [4], Taylor [5], Christafore and Leguizamon [6] examining school proficiency test passage and house price, and Leguizamon and Ross [7] looking at both proficiency passage and expenditures.[ii] That the question is so often studied is a testament both to its importance and the difficulty in coming up with a uniformly accepted estimation approach.

Nguyen-Hoang and Yinger [1] cover a litany of ways researchers have tried to identify school quality in house price hedonics, including fixed effects, spatial econometrics, and instrumental variables. Each approach has its drawbacks. While instrumental variables estimation is theoretically appealing, it is difficult to come up with an instrument that is correlated with school quality but uncorrelated with the error term. Attempts to do so successfully are "debatable", in their words; they do have praise for Rosenthal [9], however. Rosenthal instruments for proficiency test passage using a dummy variable for whether a school inspection has been done recently. State schools in England have to be inspected at least once every four years, and having an inspection recently is likely to be uncorrelated with unobserved neighborhood characteristics. Such an instrumentation strategy cannot be applied to data from nations like the United States that do not have inspections.

A minority of studies explore the capitalization of school spending into house prices (Nguyen-Hoang and Yinger [1]), and only a few of these include both spending and an outcome measure like proficiency passage. Seo and Simons [10] find both expenditures and a host of school output measures simultaneously capitalized into house prices. Brasington and Haurin [11] include proficiency scores and expenditures per pupil simultaneously, finding both measures positive and statistically significant in 12 out of 14 regressions. Hilber and Mayer [2] find both expenditures and test scores capitalized, the degree of capitalization varying by housing supply elasticity. Leguizamon and Ross [7] find both expenditures and proficiency passage capitalized into house price in four out of five urban areas in their spatial Durbin model.

Aside from the relationship between schooling and house prices, other important objectives of the current paper are to explore the relationship between house prices and people's use of public and private schools, as well as their opinions about public and private schools. Rosen's [12] hedonic theory suggests people should bid more for housing in areas with high-performing public schools, but it is less clear whether a person's use of public schools should affect bids. Urban areas in the United States in particular are typically characterized by a broad range of public school districts that vary in quality. The supply and demand conditions in each area determine equilibrium attribute prices, and people with the highest bids for public school quality should outbid others for these houses. People with the strongest taste for public schooling might be people who use the public schools. Previous studies find a link between house size and the willingness to pay for school quality (e.g., Bayer, Ferreira, and McMillan [13]). But it is unclear whether people are willing to pay more for a house--holding constant school outcomes and inputs--just because they have children who will use the public schools.

While numerous studies look at house prices and public school quality, few studies look at house prices and private school quality. Most of the studies that we found use the U.S. Census variable representing the percent of residents who attend a private school. The results are anything but unanimous. Seo and Simons [10] find it positively related to house prices in the year 2000, unrelated in 2005, and negative in their spatial error regressions. Zahirovic-Herbert and Turnbull [14] find it negatively related to house prices about half the time, while Brasington [15] finds it consistently negative. Fack and Grenet [16] use a slightly different measure of private schooling, finding that houses near a large concentration of private schools experience a smaller premium for public school quality. The current study has more detailed data. We know what homebuyers think about the quality of their nearest private school, and we know which people use the private schools, so we will see if attitudes about and usage of private schools affect the prices people pay for their houses.

Table 1. Variable Means, Definitions and Sources

Variable Name	Definition (Source)	Means (Std. Dev.)
House price	Sale price of single-family detached house in U.S. dollars in year 2000 (1); natural log used in reported regressions	132,660 (74,380)
Proficiency test passage	Percent of students in school district who passed Ohio 12th grade math proficiency test at basic or advanced level in 2000-2001 school year (2)	59.3 (15.2)
Expenditures per pupil	Total expenditure per pupil at school district level in thousands of U.S. dollars, for 2000-2001 school year (2)	8.2 (1.2)
Property tax rate	Tax year 2000 class 1 (agricultural and residential) effective property tax rate in school district in mills (6)	33.9 (6.9)
Single story	Dummy variable = 1 if house is only one story in height, = 0 otherwise (1)	0.39 (0.49)
Garage	Dummy variable = 1 if house has a garage, = 0 otherwise (1)	0.66 (0.48)
Air conditioning	Dummy variable = 1 if house has central air conditioning, = 0 otherwise (1)	0.33 (0.47)
Fireplace	Dummy variable = 1 if house has a fireplace, = 0 otherwise (1)	0.55 (0.60)
Full bathrooms	Number of full bathrooms (toilet plus shower) in the house (1)	1.4 (0.6)
House age	Age of the house in hundreds of years (1)	0.46 (0.30)
House size	Size of the building in thousands of square feet (1)	1.6 (0.6)
Patio	Dummy variable = 1 if house has a patio, = 0 otherwise (1)	0.08 (0.27)
Deck	Dummy variable = 1 if house has a deck, = 0 otherwise (1)	0.09 (0.29)
Commute time	Average commute time in minutes for persons 16 years and over not working at home in census block group who were both employed and at work during the reference week (3)	23.4 (3.5)
Distance to hazard	Distance in miles from house to nearest point-source environmental disamenity (4)	0.95 (0.62)
Owner occupied	Percent of occupied housing units in census block group that are occupied by owners rather than renters (3)	71.8 (21.1)
Poverty rate	Percent of persons in the census block group living in a family whose total family income is below the poverty threshold appropriate for that family (3)	7.7 (8.4)
Neighborhood income	Median income of households in census block group in tens of thousands of U.S. dollars (3)	5.1 (2.2)
Respondent income	Family income of survey respondent in tens of thousands of U.S. dollars (5)	7.9 (5.7)
Respondent grad degree	Dummy variable = 1 if survey respondent has a graduate degree as highest education, = 0 otherwise (5)	0.21 (0.41)
Respondent bachelors degree	Dummy variable = 1 if survey respondent has a bachelor's degree as highest education, = 0 otherwise (5)	0.32 (0.47)
Respondent white	Dummy variable = 1 if survey respondent self-identified as ethnically white, = 0 otherwise (5)	0.86 (0.35)
Respondent age	Age of respondent in years (5)	42.9 (12.6)
Respondent very liberal	Dummy variable = 1 if survey respondent self-identified as being politically very liberal, = 0 otherwise (5)	0.10 (0.30)
Respondent liberal	Dummy variable = 1 if survey respondent self-identified as being politically liberal, = 0 otherwise (5)	0.19 (0.39)
Respondent first house	Dummy variable = 1 if this house is first one survey respondent has owned, = 0 otherwise (5)	0.46 (0.50)
Respondent buy realtor	Dummy variable = 1 if survey respondent used a realtor to buy this house, = 0 otherwise (5)	0.79 (0.41)
% class 1 value	Percent of property value in 2000 (land and buildings together) that is Class 1 (residential and agricultural) property, by school district (7)	33.9 (6.9)
Disciplinary actions	Number of disciplinary actions per 100 students at school district level for 2000-1 school year; actions include expulsions, out of school and in-school suspensions, in-school alternative programs (special classes or programs), Saturday suspensions, emergency removal of student by school official, removal of students with disabilities by impartial state appointed hearing officer (8)	49.4 (36.1)
Density	Persons per square mile in school district (9)	2785 (1571)

Attend public	Dummy variable = 1 if survey respondent sends school-aged children to public school, = 0 otherwise (5)	0.34 (0.47)
Attend private	Dummy variable = 1 if survey respondent sends school-aged children to private school, = 0 otherwise (5)	0.12 (0.33)
Attend both	Dummy variable = 1 if survey respondent sends children to both public and private schools, = 0 otherwise (5)	0.04 (0.19)
Private school excellent	Dummy variable = 1 if survey respondent says his nearest private school is excellent, = 0 otherwise (5)	0.32 (0.47)
Public school excellent	Dummy variable = 1 if survey respondent says his nearest public school is excellent, = 0 otherwise (5)	0.28 (0.45)
State indicators passed	Proportion of state of Ohio indicators that a public school district has passed in 2005-2006 school year, indicators based on up to 25 state-administered student exam passage (2)	0.59 (0.36)
Private school math	Percentage of private school students at or above proficient in math section of 9th grade state-administered proficiency tests for average of 2000 and 2001 test years for nearest private school to each house (10)	50.7 (25.3)
Number of observations = 1186, except 879 for Private school math (due to privacy concerns for small private schools) and State indicators passed in same regression. Sources: (1) First American Real Estate Solutions [19], (2) Ohio Department of Education [20], (3) Geolytics [21], (4) Ohio EPA [22], (5) phone survey, (6) Ohio Department of Taxation [23], (7) Ohio Department of Taxation [24], (8) Ohio Department of Education [25], (9) usa.com [26], (10) author collected from Sheila Milligan of Ohio Department of Education 8/19/05		

3. Institutional Setting and Data

The current study uses data from Ohio in the 2000s. Ohio is the 7th most populous state in the United States, with 11.5 million residents. It has seven sizeable urban areas that have experienced different fates in the last decades, with Cleveland shrinking, Columbus growing fairly rapidly, and Cincinnati growing at a moderate pace, so that all three had approximately 2 million residents in 2010. Toledo, Dayton and Akron have about 700,000 residents each, with a fast-declining Youngstown down to 558,000 residents. Ohio is also characterized by numerous small industrial towns, fairly prosperous farming communities in the middle and west of the state, and poor Appalachian communities in the south and east.

Ohio has 611 public school districts. 75% of these participate in an inter-district open enrollment program. The City of Cleveland has a school voucher program, and the rest of the state has a lesser-known private school voucher program called EdChoice. Ohio has 1,249 private schools, concentrated in the large urban areas; about 13% of K-12 students attend private schools. Ohio also has 354 charter schools, which are publicly funded but privately operated. Local taxes provide about half of the funding for a typical public school district, so local tax decisions greatly influence total school spending. Ohio has a foundation funding program in which property-rich school districts subsidize property-poor districts to some degree, with about one third of the typical school district's funding coming from the state government foundation grant. The remaining 17% or so of school districts' funding comes from the state lottery, grants from the national government, and other miscellaneous sources.

The rich data used in this paper is based on the survey described in Brasington and Hite [17, 18]. Readers are referred to these papers for more detail about the phone survey, but we reiterate here that despite a relatively low response rate our data are fairly representative of Ohio homeowners.[iii] The 2006 American Fact Finder shows that Ohio homeowners are typically in the 45-54 age range, while the mean for our sample is 43. The median Ohio homeowner's highest education is some college or an associate's degree; the 47th percentile of our sample is for an associate's degree or less. About 8% of homeowners in Ohio are black; our sample consists of 10% black respondents. And the typical Ohio homeowner is in the $50,000 - $74,999 income range, while our sample has a mean income of $78,700. When the survey data are combined with data from eight other sources, the result is a rich collection of information on 1186 Ohio homeowners, their houses, their neighborhoods, and the public services they receive and how much they pay for them in property taxes. Table 1 shows variable names, means, definitions and sources.

4. Econometric Approach

Identification issues plague hedonic studies. The current study addresses identification through three channels: (1) instrumental variables, (2) individual buyer characteristics, and (3) a system of equations describing the reasons people bought their houses.

4.1. Instrumental Variables

Unlike England, Ohio does not have state-sponsored inspections, so the instrument used in Rosenthal [9] is unavailable. Having a recent state inspection is probably related to how orderly a school is run. In the spirit of Rosenthal [9], then, the current study instruments for proficiency test passage with student discipline problems. It would be helpful to researchers if student discipline data were widely available for use as an instrument. We looked up several state departments of education web sites; most U.S. states seem to collect discipline data, and most of these make it publicly available.

A good instrument must be exogenous, unrelated to the error term, and related to the variable for which it

instruments. Some might argue that disciplinary actions are not exogenous because this measure, too, is related to housing prices. However, a test of exogeneity of an instrument is to include it as a regressor. When disciplinary actions are included in the house price hedonic, the variable has a *t*-ratio of -0.21 and a *p*-value of 0.84, clearly failing to reject the null hypothesis of no relationship, thus indicating exogeneity. A Hansen's *J*-test (discussed later) fails to reject the null hypothesis of joint exogeneity of disciplinary actions and the other instruments. Intuitively, the number of discipline problems in a school district is probably exogenous to the buyer of a house. A voter is unlikely to be able to influence the discipline policy in a school, and even if she could, the unruliness of student behavior has a component that is beyond school administrators or parents to influence.

The exogeneity of discipline problems implies that it is not related to the error term. Indeed, the raw correlation between indiscipline and the error term is zero to four digits.[iv] One might think that discipline problems are related to the error term because discipline problems are related to parent involvement, the discipline that students receive at home, and the characteristics of the neighborhood in which a student lives. But to the extent possible these influences have been extracted from the error term and used as explanatory variables in the house price hedonic, which contains respondent-level data on income, education, age, race, and political persuasion, as well as neighborhood-level data on poverty, income, and percent owner-occupied housing. The inclusion of these explanatory variables helps explain the low correlation between discipline problems and the error term.

In addition to exogeneity, in order to be a valid instrument discipline problems must be sufficiently related to student achievement. Theory would suggest a more disruptive school environment to be linked to lower academic achievement, and indeed the pairwise correlation between the number of disciplinary actions in a school district and proficiency passage is -0.52. A Nelson and Startz [27] test also suggests that discipline is sufficiently highly related to math proficiency to be an appropriate instrument.[v] Other diagnostic tests, discussed later, further support the validity of discipline problems and the other instrumental variables.

The current study also instruments for the tax rate. Although property tax rates may be exogenous under certain circumstances (Nguyen-Hoang and Yinger [1]), experimentation in the current data set shows more theoretically consistent results when it is treated endogenously. The instrument chosen is the percentage of land value in a school district that is class 1 (agricultural and residential), as opposed to class 2 (commercial and industrial). A proper instrument must be exogenous, unrelated to the error term, and related to the variable for which it instruments. One might wonder if the percentage of class 1 land value is endogenous because it is related to house prices; however, when this variable is added to the list of regressors in the house price hedonic, it has a *t*-ratio of -0.83 and a *p*-value of 0.41, failing to achieve statistical significance. Its exogeneity is further suggested by a Hansen's *J*-test (discussed later) that fails to reject the null hypothesis of joint exogeneity of class 1 land value and the other instruments. Furthermore, in order to be exogenous, the percent of class 1 land value cannot be highly correlated with the error term; in fact, its correlation with OLS residuals is only 0.0059.

The other desirable quality of a valid instrument is that it be sufficiently correlated with the variable for which it instruments. Previous literature shows that residents' choice of tax rates is related to its reliance or lack of reliance on a commercial and industrial tax base (e.g. Ladd [28]). In the current data set, the instrument has a 0.31 correlation with the property tax rate, and it passes the Nelson and Starz [27] test with a calculated test statistic of 117.4 versus a critical value of 2. Other diagnostic tests, discussed later, further support the validity of the percentage of class 1 land value and the other instrumental variables.

The other included measure of school quality is expenditures per pupil. Like proficiency tests, it might be endogenous. Hilber and Mayer [2] suggest using the proportion of undeveloped land in a school district as an identifying instrument. While the proportion of undeveloped land is unavailable for the Ohio data set, population density is available. Population density and the proportion of undeveloped land are related to each other: the more undeveloped land there is, the lower is population density. Hilber and Mayer [2] demonstrate that the percent of undeveloped land is related to expenditures but unrelated to house prices and the error term, making it a valid choice of instrument.

More diagnostic tests for instrument validity are also available. These tests examine the validity of the set of instruments--discipline problems, class 1 property value, and population density--as a group. The instruments reject the null of under-identification in an Anderson [29] LM test with a chi-square test statistic of 80.1, and a *p*-value of 0.0000. They also pass the Cragg and Donald [30] test of weakly identified instruments with a calculated Wald *F* statistic of 27.9. More diagnostic tests are available when using robust standard errors. In this regression, the instruments again pass the Cragg and Donald [30] test, and two Kliebergen and Paap [31] tests become available. With a critical value of 10, the Kliebergen and Paap Wald *F* of 34.2 rejects the null of weak instruments, while the Kliebergen and Paap LM statistic of 82.3 rejects the null of under-identification with a *p*-value of 0.0000. In order to run a Hansen's *J* or Sargan [32] test of over-identification of all instruments, it is necessary to add a fourth instrument for the three endogenous regressors. A dummy variable for whether the respondent thinks his assigned public school is excellent is used—not because we believe it is necessarily a good instrument, but because it is available. With this extraneous instrument added, a Sargan test becomes available and yields a test statistic of 1.25. The

p-value is 0.26, failing to reject the null hypothesis and suggesting that we cannot reject the exogeneity of the instruments.[vi]

4.2. Endogenous Sorting

Another problem with traditional house price hedonic studies is that they fail to address what has become known as residential sorting or endogenous sorting. With respect to school quality, researchers who investigate the relationship between schooling and bids for housing traditionally ignore the general equilibrium context of this relationship. When residents sort to a 'good' school district, neighborhood demographic characteristics change, also, and these latter changes have their own effect on house prices (Bayer, Ferreira, and McMillan [13]). As Nguyen-Hoang and Yinger [1] put it, "The question is not only whether school quality affects house values, but also whether school-capitalization studies can detect the sorting process that allocates households with a high marginal willingness to pay for education to some jurisdictions and households with a low marginal willingness to pay to others."

Our study attempts a new, simple approach to help address endogenous sorting. Nguyen-Hoang and Yinger [1] suggest that including micro-neighborhood data in a house price hedonic would help alleviate the problem of endogenous sorting. We can do one better than micro-neighborhood data because we know the characteristics of the individuals who buy each house in our sample. By including individual-level data we help model the preferences that govern people sorting into different school districts, police districts, tax districts, and houses exposed to different levels of environmental quality.[vii] The individual-level variables added to capture preferences are a respondent's age, whether his highest education completed is a graduate degree or bachelor's degree, whether she is white, family income, whether he is liberal or very liberal, whether this house is the first she has owned, and whether he bought the house with help from a realtor.

4.3. System of Equations

The richness of the data set allows us to examine the reasons people purchased their current house. If Tiebout sorting suggests people move to areas that match their preferences for public services and taxes, a regression that addresses sorting should account for these preferences. Our survey had respondents select the reasons they chose their current house, for example, whether "neighborhood is safe" was one of the two most important reasons a respondent chose her current residence, so our regression is based on a system of equations that incorporates these preferences, as follows:

(1) ln (house price) = f(public services, taxes; house, buyer and neighborhood characteristics)
(2) bought house for schools = f(proficiency test passage, use of schools; house, buyer and neighborhood characteristics)
(3) bought house for low pollution = f(distance to nearest hazard, buyer and neighborhood characteristics)
(4) bought house for safety = f(crime rate, buyer and neighborhood characteristics)
(5) bought house for low taxes = f(property tax rate, buyer and neighborhood characteristics)

Equations (1) through (5) are estimated simultaneously with correlation allowed between the error terms, using three-stage least squares. The buyer and neighborhood characteristics in Equations (1) – (5) are not identical, helping identify these equations by the order condition.[viii] As discussed previously, proficiency test passage, expenditures per pupil, and the property tax rate in Equation (1) are treated endogenously, using disciplinary actions, population density, percent class 1 land value, and the other exogenous variables from equations (1) through (5) as instruments.

5. Results and Discussion

5.1. Baseline Regression

The results of the baseline regression are shown in Table 2. The explanatory variables that are traditional in house price hedonic studies generally have the expected sign. Many of the buyer characteristic variables are also related to house price, as in Brasington and Hite [17]. Their significance suggests that the regression is able to mitigate endogenous sorting bias in the manner that Nguyen-Hoang and Yinger [1] propose. The focus variables are also statistically significant with the expected sign. The elasticity of house price with respect to property taxes is -0.37.

Math proficiency test scores are positively related to house price, holding constant spending per pupil, taxes, and the other control variables. The elasticity of house price with respect to math proficiency is 0.47, indicating that a 10% rise in proficiency passage is associated with a 4.7% rise in bids for housing. Stated differently, a one standard deviation rise in math proficiency is associated with a 10.7 percent rise in constant-quality house price. This is a somewhat larger effect than the 7.1% rise found in Brasington and Haurin [11], and much larger than the less-than-four percent found in the papers surveyed by Nguyen-Hoang and Yinger [1]. The results may suggest that studies that are less careful with identification understate the capitalization of schooling outputs into house price.

Table 2. Baseline Hedonic 3SLS Regression Dependent Variable = Natural Log of House Price

Explanatory Variable	Parameter Estimate (*t*-ratio)	Explanatory Variable	Parameter Estimate (*t*-ratio)
Proficiency test passage	0.0080** (6.75)	Distance to hazard	-0.0081 (0.54)
Expenditures per pupil	0.13** (8.18)	Owner occupied	-0.0014* (2.52)
Property tax rate	-0.011** (4.62)	Poverty rate	-0.0097** (7.38)
Single story	-0.0065 (0.30)	Neighborhood income	0.028** (4.03)
Garage	0.039* (2.12)	Respondent income	0.0040** (2.69)
Air conditioning	-0.021 (1.03)	Respondent grad degree	0.11** (4.77)
Fireplace	0.077** (4.81)	Respondent bachelors degree	0.079** (4.16)
Full bathrooms	0.048* (2.41)	Respondent white	0.062** (2.67)
House age	-0.32** (3.06)	Respondent age	0.00095 (0.14)
House age squared	0.071 (0.83)	Respondent very liberal	0.050* (1.84)
House size	0.50** (6.35)	Respondent liberal	-0.00017 (0.01)
House size squared	-0.046* (2.50)	Respondent first house	-0.045* (2.39)
Patio	0.0071 (0.24)	Respondent buy realtor	0.043* (2.25)
Deck	-0.022 (0.74)	Constant term	9.81** (58.95)
Commute time	-0.0066** (2.69)		

Number of observations = 1186. House price estimation run simultaneously with four other regressions explaining the determinants of why people bought their house for low pollution, for the schools, for safety, and for low taxes. Results of other regressions available upon request. Proficiency test passage, expenditures per pupil, and property tax rate are treated endogenously using instrumental variables. Parameter estimate shown with absolute value of t-ratio in parentheses below. * = statistically significant at 0.10 level, ** = statistically significant at 0.01 level. Pseudo R-squared = 0.73, chi-squared = 3237.5.

The expenditures capitalization results deserve special discussion. First, holding math proficiency constant, school expenditures are positively related to house prices. The magnitude of the relationship is large; with an elasticity of 1.07, a one percent increase in expenditures per pupil is related to a 1.07 percent increase in house price, all else constant. This is more than twice as strong as the 0.49 elasticity found in Brasington and Haurin [11], the 0.33 elasticity found in Hilber and Mayer [2], or the 0.21 elasticity found in Bhattarai, et al. [34]. Other studies with (we argue) less properly identified house price regressions seem to understate the importance of school inputs to house prices. According to Nguyen-Hoang and Yinger [1], p. 37, "In cases where both spending and outputs (e.g., test scores) are included, the estimated coefficient of spending is open to interpretation. Because spending in this case can be a proxy for other unspecified outputs, the coefficient represents, holding test scores constant, parental concern either about spending or about unspecified outputs that are correlated with spending." Our guess is that test scores would be correlated with many other outputs that are correlated with spending, like dropout rates, promotion rates and graduation rates. On the other hand, Nguyen-Hoang and Yinger's observation that spending might be valued apart from its potential to improve quality is worth exploring in depth.

5.1.1. Expenditures as Signaling Mechanism

We propose that, holding proficiency test passage constant, school spending is valued in itself because it acts as a signaling mechanism. Parents in a school district are concerned about educational quality, and the premium buyers pay in the housing market reflects the relative scarcity of high-performing public schools. But to reinforce this focus on quality, spending serves as a signal that high-performing schools are a priority for the community. Apart from making sure homework is done and tutoring happens in schools, one way every member of the community can 'support' their public school is by passing local tax levies (Hilber and Mayer [2], p. 84).

The additional spending may not directly enhance quality. While some studies find improved outcomes from increased spending on certain school inputs, many others do not (Glewwe [35]). One may expect more impact in developing nations, where spending and educational inputs begin at a lower level, and where the marginal productivity of an additional input is larger. But, as an illustrative example,

Fuller and Clark [36] survey the effects of reduced class size, a variable that is commonly espoused to enhance student outcomes. They find the anticipated relationship with outcomes in only 9 of 26 studies that look at primary schools and 2 of 22 studies that look at secondary schools in developing nations.

The lack of connection between spending and outcomes is evidence in favor of signaling. In fact, the signaling hypothesis put forward by this paper is supported by two different trains of thought on the meaning of capitalization. One view of capitalization is that it indicates that more resources are being spent than necessary to provide a given level of public services (Hoyt [37], Epple et al. [38]). By this view, holding proficiency outcomes constant, the capitalization of expenditures into house prices is evidence of productive inefficiency. But if the additional spending is a signaling mechanism, the signal—while costly--might serve to attract more education-conscious residents and improve peer group effects, bolstering student achievement, which would show up in the proficiency test scores. Another view of capitalization is that it indicates allocative inefficiency: that too much money is being spent on a particular public service (Brueckner [39], Taylor [40]). If this view is correct, the capitalization of school spending into house prices indicates that more is being spent on schooling services than is optimal. Why would such an outcome happen? If we assume rational agents, over-spending on schooling services is consistent with residents using spending as a signal, a signal that the community puts a priority on education.

5.2. Treating All Variables as Exogenous

The baseline results rely in part on instrumentation to achieve identification. The first experiment we perform is to treat all explanatory variables as exogenous. This has the effect of turning the three stages least squares estimation into a system of seemingly unrelated regressions. The results are shown in Table 3.

Although proficiency, expenditures, and tax rate remain statistically significant, there is a pronounced change in the magnitude of the estimates, suggesting there was noticeable omitted variable bias alleviated by the instrumentation. Tax capitalization goes from an elasticity of -0.37 to -0.12. Proficiency test capitalization is halved, from 0.47 to 0.21. The new (biased) 0.21 estimate for proficiency elasticity is more in line with the small effects found in the studies surveyed by Nguyen-Hoang and Yinger [1]. The capitalization of expenditures is also halved, from 1.07 to 0.51. The new (biased) 0.51 estimate is closer to the 0.21 elasticity of Bhattarai, et al. [34], who also study Ohio, and closer to the 0.33 estimate from Hilber and Mayer's [2] Massachusetts study. A Breusch-Pagan test shows that it is proper to estimate the house price hedonic in a system of equations modeling attribute choice. The chi-squared test statistic of 80.3 rejects the null hypothesis of independent equations with a *p*-value less than 0.000.

Let us now treat proficiency, expenditures, and taxes as endogenous again and perform additional robustness checks. Omitting all Census block group-level controls makes the parameter estimate of property taxes go from -0.011 to -0.010, proficiency go from 0.0080 to 0.0106, and expenditures remain at 0.13. Omitting instead all buyer-specific characteristics from the hedonic makes the parameter estimate of property taxes go from -0.011 to -0.012, proficiency go from 0.0080 to 0.0102, and expenditures go from 0.13 to 0.15. Removing all structural house characteristics except building size and age, the parameter estimate of taxes goes from -0.011 to -0.012, proficiency goes from 0.0080 to 0.0093, and expenditures goes from 0.13 to 0.14. There is no change in statistical significance for any robustness check.

Table 3. Seemingly Unrelated Regression (No Instrumentation) Dependent Variable = Natural Log of House Price

Explanatory Variable	Parameter Estimate
Proficiency test passage	0.0036** (5.31)
Expenditures per pupil	0.062** (7.22)
Property tax rate	-0.0034* (2.29)
Number of observations = 1186. House price estimation run simultaneously with four other regressions explaining the determinants of why people bought their house for low pollution, for the schools, for safety, and for low taxes. Results of other regressions available upon request. Other explanatory variables from baseline regression are included but output is suppressed. Proficiency test passage, expenditures per pupil, and property tax rate are treated exogenously. Parameter estimate shown with absolute value of t-ratio in parentheses below. * = statistically significant at 0.10 level, ** = statistically significant at 0.01 level. Pseudo R-squared = 0.74, chi-squared = 3464.3.	

Table 4. If Have Children Who Attend School Dependent Variable = Natural Log of House Price

Explanatory Variable	Parameter Estimate (*t*-ratio)	Explanatory Variable	Parameter Estimate (*t*-ratio)
Proficiency test passage	0.0082** (6.90)	Attend public	-0.023 (1.26)
Expenditures per pupil	0.13** (8.14)	Attend private	0.013 (0.51)
Property tax rate	-0.011** (4.63)	Attend both	-0.0012 (0.03)
Number of observations = 1186. Three stage least squares house price estimation run simultaneously with four other regressions explaining the determinants of why people bought their house for low pollution, for the schools, for safety, and for low taxes. Results of other regressions available upon request. Other explanatory variables from baseline regression are included but output is suppressed. Proficiency test passage, expenditures per pupil, and property tax rate are treated endogenously with instrumental variables. Parameter estimate shown with absolute value of t-ratio in parentheses below. * = statistically significant at 0.10 level, ** = statistically significant at 0.01 level. Pseudo R-squared = 0.73, chi-squared = 3239.6.			

Table 5. Private School Attendance and Attitudes Dependent Variable = Natural Log of House Price

Explanatory Variable	Parameter Estimate (*t*-ratio)	Explanatory Variable	Parameter Estimate (*t*-ratio)
Proficiency test passage	0.0080** (6.90)	Attend private	-0.027 (0.81)
Expenditures per pupil	0.13** (8.13)	Private school excellent	0.0070 (0.38)
Property tax rate	-0.011* (2.16)	Attend private * private school excellent	0.097* (2.01)
Number of observations = 1186. Three stage least squares house price estimation run simultaneously with four other regressions explaining the determinants of why people bought their house for low pollution, for the schools, for safety, and for low taxes. Results of other regressions available upon request. Other explanatory variables from baseline regression are included but output is suppressed. Proficiency test passage, expenditures per pupil, and property tax rate are treated endogenously with instrumental variables. Parameter estimate shown with absolute value of t-ratio in parentheses below. * = statistically significant at 0.10 level, ** = statistically significant at 0.01 level. Pseudo R-squared = 0.73, chi-squared = 3266.1.			

5.3. House Prices and Type of Schools Children Attend

The next experiment continues to use three-stage least squares, but focuses on whether homebuyers who have school-aged children pay a premium for their house, controlling for input and output measures of quality. Specifically, dummy variables are added for whether a survey respondent has a child who attends public school, private school, or both public and private schools. The results are shown in Table 4.

None of these variables is significantly related to house price, all else constant. The results are consistent with the argument of Hilber and Mayer [2], Brunner and Sonstelie [41], and other researchers, who argue that non-users of schools are concerned about school quality for the capitalization effects. Actually using the schools should not affect a person's bid for housing over and above proficiency test passage rates and spending per pupil. Rosen [12] would probably agree that, if the market for housing attributes is characterized by perfect competition, and people with the strongest bids for schooling end up with the houses with the largest quantities of schooling, the capitalization should be between the school quality measures and housing, and not the taste parameters that affect the demand for schooling.

5.4. House Prices and Subjective Opinions about School Quality

5.4.1. Opinions about Private Schools

The next experiment delves into the world of attitudes. Controlling for objective measures of public school quality, does a person's attitude toward his nearest private school and his usage of private schools affect his bid for housing? To address this question, the baseline regression adds a variable for whether the individual uses private schools, whether the individual believes the nearest private school is excellent, and an interaction between these variables. The results are shown in Table 5.

Only the interaction variable is statistically significant, but it is a robust finding, and its magnitude is meaningful. If a homebuyer uses private schools *and* thinks it is excellent, he pays a 10% premium for the house, all else constant. At first glance this result seems contrary to the prior finding about a homebuyer using public or private schools, but there is one critical difference: the current regression includes a measure of private school quality (the respondent's opinion). Some research suggests that people's perceptions of school quality are not based on accurate information, and that even people with the most information filter this information in a biased manner (e.g., Buckley and Schneider [42]). Private school quality is even harder information to come by than public school quality.

The current study suggests, though, that regardless of the unobserved underlying quality, both thinking the nearest private school is excellent and using a private school leads a person to pay a substantial premium for the house. It is interesting to note that the un-interacted 'private school

excellent' variable is not statistically significant. An additional test for whether it is attitudes about the school or the lack of objective quality measures that is driving the interaction term result would be to replicate the experiment for public school users.

5.4.2. Opinions about Public Schools

The next experiment, then, is to account for a homebuyer's use of and attitudes toward public schools. The baseline regression is augmented with a dummy variable for whether a person has a child who uses public schools, a dummy for whether the homebuyer believes his assigned public school is excellent, and an interaction between the two. The results are shown in Table 6.

None of these variables achieves statistical significance. The regression already controls for proficiency test passage and spending per pupil, and previous regressions showed no independent house price premium for using public schools. But previous regressions also showed that people who attend private schools and think their nearest private school is excellent pay a house price premium. The lack of premium for people who both use public schools and think their public school is excellent suggests that the 'attend private * private school excellent' result most likely captures private school quality. The lack of significance for 'public school excellent' is probably not driven by multicollinearity, either, as its correlation with math proficiency is 0.49: high enough to be related, but low enough to allow for independent variation.

More specifically, and contrary to Buckley and Schneider [42], the results suggests that the theory of the marginal consumer may hold water: that a motivated minority of people may collect information about (private) school quality and Tiebout-sort into areas where they can take advantage of the private schools they believe are excellent. Brunner and Sonstelie [41] provide similar evidence when they find that homeowners without children who live in high-performing public school districts are more likely to vote against California's school voucher program in 2000. They suggest the reason is to protect property values, since these homeowners are not using the schools. In fact, our survey suggests that information about public school quality may be more widely known than the theory of the marginal consumer suggests. Math proficiency and survey respondents' subjective opinions about their public school district have the following correlations: public excellent (0.49), public good (0.07), public fair (-0.23), public not good (-0.22), public poor (-0.28). The relationship is essentially monotonic in quality.

Table 6. Public School Attendance and Attitudes Dependent Variable = Natural Log of House Price

Explanatory Variable	Parameter Estimate (*t*-ratio)	Explanatory Variable	Parameter Estimate (*t*-ratio)
Proficiency test passage	0.0090** (6.89)	Attend public	-0.016 (0.75)
Expenditures per pupil	0.14** (8.28)	Public school excellent	0.040 (1.44)
Property tax rate	-0.011** (4.79)	Attend public * public school excellent	-0.0069 (0.19)
Number of observations = 1186. Three stage least squares house price estimation run simultaneously with four other regressions explaining the determinants of why people bought their house for low pollution, for the schools, for safety, and for low taxes. Results of other regressions available upon request. Other explanatory variables from baseline regression are included but output is suppressed. Proficiency test passage, expenditures per pupil, and property tax rate are treated endogenously with instrumental variables. Parameter estimate shown with absolute value of t-ratio in parentheses below. * = statistically significant at 0.10 level, ** = statistically significant at 0.01 level. Pseudo R-squared = 0.72, chi-squared = 3213.2.			

Table 7. Alternative measures of school quality Dependent Variable = Natural Log of House Price

Explanatory Variable	Parameter Estimate (*t*-ratio)	Explanatory Variable	Parameter Estimate (*t*-ratio)
State indicators passed	0.24** (4.09)	Attend private	0.11* (1.76)
Expenditures per pupil	0.11** (6.22)	Private school math	0.00091* (2.17)
Property tax rate	-0.0062** (2.72)	Attend private * Private school math	-0.0012 (1.21)
Number of observations = 1186. Three stage least squares house price estimation run simultaneously with four other regressions explaining the determinants of why people bought their house for low pollution, for the schools, for safety, and for low taxes. Results of other regressions available upon request. Other explanatory variables from baseline regression are included but output is suppressed. State indicators passed, expenditures per pupil, and property tax rate are treated endogenously with instrumental variables. Parameter estimate shown with absolute value of t-ratio in parentheses below. * = statistically significant at 0.10 level, ** = statistically significant at 0.01 level. Pseudo R-squared = 0.72, chi-squared = 2339.3.			

5.4.3 Alternative Measures for Public and Private Schools

A final experiment replaces public school math test performance with a measure of school district quality imposed by the State of Ohio Department of Education: State indicators passed. This measure is published by the state on its Interactive Local Report Cards web site, and the results are often reported in local newspapers. Another modification is to replace the subjective Private school excellent variable with a more objective measure. The author collected information on the percentage of private school students who passed the 9th grade math proficiency test. For privacy concerns, the state only released the average of two years of data (2000-2001 and 2001-2002), and any private school with less than 11 students taking the test was not reported. Still, 879 houses remain in the sample, and the results in Table 7 are achieved:

The results of Table 7 track those of Table 5 closely. The new measure of public school quality is positively related to house price, all else constant, like the old one. The elasticity of State indicators passed is only 0.14 compared to 0.47 for Proficiency test passage, which was based solely on math passage. Private school attendance is still positively related to house price. All else constant, attending private school is associated with an 11% higher house price. The new objective measure of private school quality, Private school math, is positively related to house price too, with an elasticity of 0.046. The results continue to support the theory of the marginal consumer, because houses near better-performing private schools command a premium.

6. Conclusions

The current study employs a new set of identification strategies to explore the relationship between house prices and school quality. It also explores the role of people's use of and attitudes toward public and private schools, and how these are related to house prices.

The paper identifies what it argues are appropriate new instruments for proficiency test scores and the property tax rate, and it more or less borrows from Hilber and Mayer [2] in instrumenting for school expenditures. Instrumenting makes a big difference in the estimates, more than doubling the elasticities of test scores, expenditures, and taxes with respect to house prices. The instruments pass a variety of diagnostic tests to support their validity.

Beyond instrumental variables, the current study attempts to improve identification by adding buyer characteristics to the house price hedonic. These individual buyer characteristics substitute for the micro-neighborhood variables used by Bayer, Ferreira and McMillan [3] to address endogenous sorting. We also estimate the hedonic in a system of equations that models the reasons a person bought his house. The equations in the system are shown to be related to each other, and modeling house purchase with various public finance variables in mind is consistent with Tiebout sorting.

We find the elasticity of constant-quality house prices with respect to property tax rates is -0.37. We find the elasticity of house prices with respect to proficiency test scores is -0.47. Interpreted another way, a one standard deviation increase in test scores is associated with a 10.7% increase in house prices, whereas the papers surveyed in Nguyen-Hoang and Yinger [1] almost all have estimates of less than 4%. We find an expenditures per pupil elasticity of house price of 1.07. This is more than twice as strong as the elasticities found in the literature. Supported by the results of an experiment where we treat test scores and expenditures as exogenous, we suggest that most hedonic studies under-estimate the true strength of the link between school quality and house prices.

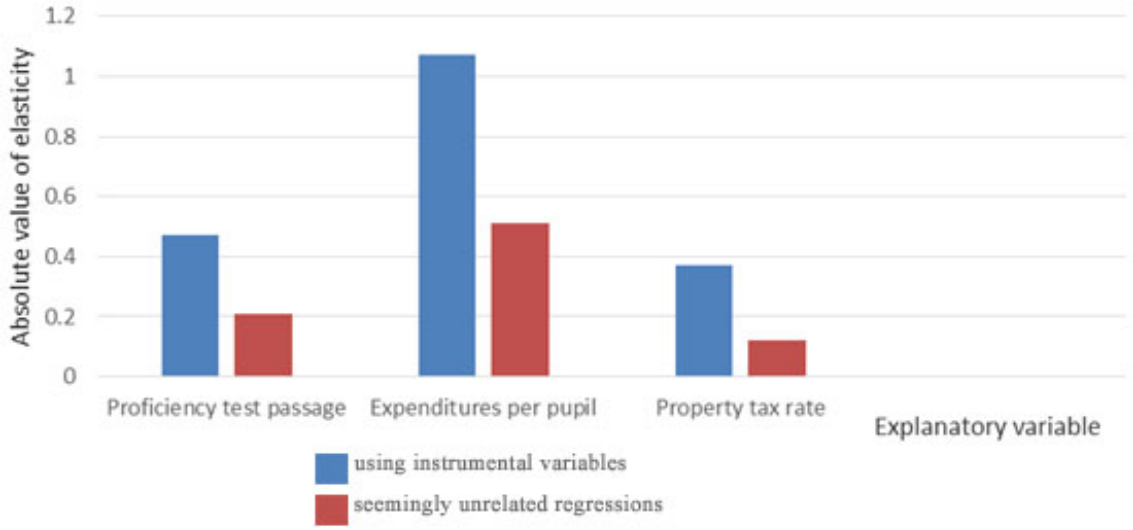

Figure 1. House Price elasticities with and without instrumentation

We propose that expenditures per pupil is capitalized into house price – holding proficiency passage constant – because expenditures acts as a signaling mechanism. There is a tenuous link between school spending and student outcomes even in developing nations; and the capitalization of expenditures into house prices can be interpreted as wasteful over-spending to achieve a specific level of output, or as allocative inefficiency by over-spending. Rational voters might over-spend on schooling inputs to signal to prospective homebuyers that existing residents have a vested interest in their school district. Such signaling may draw homebuyers with similar tastes for education, who may have strong peer group effects. If the supply of such education-conscious school districts is small relative to demand, homebuyers pay a premium to live in these districts. The signaling hypothesis must be considered in the context of Ohio, in which school districts have a great deal of autonomy in choosing spending levels. A further test of the signaling mechanism hypothesis might examine the link between expenditures and house prices in areas in which school district spending and policies are largely controlled by higher levels of government, like a state or a national government.

The final set of findings pertains to the use of schools and people's attitudes toward them. Having children who attend public school, private school, or both, is unrelated to house prices, all else constant. We find this result reassuring, as the premium paid for proficiency tests and expenditures should be common to all homebuyers, regardless of whether they have school-aged children. It is also consistent with research like Hilber and Mayer [2] and Brunner and Sonstelie [35], which find that people who do not use public schools still act in ways to protect their capitalized benefits. We also find no link between house prices and attending public school or thinking the public school is excellent, all else constant, so that adding a person's attitudes does not independently result in a premium paid in the housing market. However, we find that people who use private schools *and* who believe their nearest private school is excellent pay a significant 10% premium for their house. We suggest that these attitudes proxy for private school quality, so that, by the theory of the marginal consumer, a motivated minority of homebuyers has collected sufficient information about private schools to move close to high-performing ones.

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i Hilber and Mayer [2] use the percent of undeveloped land as an instrument. Because a main goal of this study is to identify readily-available instruments, and undeveloped land does not fit this description, we adopt population density as a proxy.

ii Borge and Rattso [8] is another recent study that, like the current study, uses instrumental variables to look at property tax capitalization. Leguizamon and Ross [7] also includes the property tax rate as a control variable.

iii Our sample of Ohio homeowners may also be compared to Ohioans as a whole, who in 2006 had median age of 37.6 years, 11.8% of whom were black, whose median education level was a high school diploma (but 51st to 70th percentile had some college, no degree), and whose modal income category was $50,000 - $74,999.

iv In all cases in which the current study discusses a correlation with the error term, it means the set of residuals from an ordinary least squares regression using a linear regression with the baseline explanatory variables.

v With a critical value of 2, the Nelson and Startz test statistic is 332.08.

vi Public Excellent was also used because it was considered as a candidate to instrument for proficiency tests, the variables having a 0.49 correlation. When a truly extraneous variable like the latitude of the house is used as an over-identifying instrument, Hansen's J is 0.058 with a p-value of 0.81.

vii Brasington and Hite [17] may also inadvertently help address endogenous sorting when they implement a mixed index model because the mixed index model includes individual buyer characteristics in a house price hedonic. While they find the mixed index estimates are superior to a traditional hedonic, they find a house price hedonic that includes buyer characteristics as control variables captures many of the benefits of the mixed index model. These benefits are based on bootstrap distributions of predicted housing values, prediction variance, and predicted policy effects.

viii The exact variables used in Equation (1) are shown in the tables in this paper along with estimation results. The other equations, whose results are the focus of Brasington [33], have the following explanatory variables. Equation (2): distance to nearest hazard, respondent male, respondent ethnic minority, respondent has children aged 0-5, respondent has children aged 6-17, respondent age, respondent voted in last election, respondent enjoys NASCAR, respondent enjoys yachting, respondent volunteers in a non-specified community group, respondent is very liberal, respondent grad degree, respondent bachelors degree, respondent income, rooms in respondent's house, percent residents with blue collar occupations in respondent's census block group, unemployment rate in respondent's census block group, inverse Mills ratio from survey response correction regression. Equation (3): proficiency test passage, attend public, attend private, attend both, respondent male, respondent ethnic minority, respondent has children aged 0-5, respondent has children aged 6-17, respondent age, respondent grad degree, respondent bachelors degree, respondent volunteers as youth coach, respondent volunteers with other youth groups, respondent volunteers in schools, respondent income, percent residents with blue collar occupations in respondent's census block group, unemployment rate in respondent's census block group, inverse Mills ratio from survey response correction regression. Equation (4): crime rate, respondent male, respondent ethnic minority, respondent has children aged 0-5, respondent has children aged 6-17, respondent age, respondent grad degree, respondent bachelors degree, respondent very conservative, respondent conservative, respondent volunteers with a benevolent society, respondent volunteers in a non-specified community group, percent residents with blue collar occupations in respondent's census block group, unemployment rate in respondent's census block group, inverse Mills ratio from survey response correction regression, percent of households in respondent's census block group who receive public assistance, respondent enjoys the arts. Equation (5) property tax rate, respondent male, respondent ethnic minority, respondent has children aged 0-5, respondent has children aged 6-17, respondent age, respondent grad degree, respondent bachelors degree, respondent very conservative, respondent conservative, inverse Mills ratio from survey response correction regression, percent non-Catholics living in respondent's county, respondent refinanced house between 2000 and 2006, respondent voted in last election, respondent volunteers for non-athletic youth organization, respondent enjoys fishing, respondent is martially single.