The Impact of School Characteristics on House Prices: Chicago 1987-1991

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Abstract: Do estimates of the prices attached to different school characteristics depend on the characteristics utilised in the hedonic analysis or on the decision to use district-level or school level measures? To answer this question, we merge information from the American Housing Survey and the Illinois School Report Cards and assign to each house the school-level data for the closest school. In both district- and school-level analyses, we find that per-pupil expenditures and test scores have similar impacts on house values. However, unlike the district-level results, the school-level results imply that individuals respond to the racial composition of schools when choosing a home.

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I. Introduction

For many people, an important consideration when buying a house is the quality of the local public schools. There is a general perception that, all else equal, houses in better school districts will cost more. A number of researchers have attempted to quantify the value of school quality by applying the hedonic method developed by Rosen (1974). He showed that the implicit prices of the characteristics of heterogeneous goods can be estimated by regressing the price of the good on its characteristics. For example, regressing house prices on house and neighborhood characteristics and on tax and public service measures results in estimates of the prices for these attributes. The estimated coefficients measure the extent of capitalization into house values of property taxes and the public services these taxes finance.

This brief description of the hedonic methodology obscures the fact that quantifying the link between school characteristics and house prices has been exceedingly difficult; a fact that is signalled by the profusion of recent efforts to quantify this link (e.g., Bradbury, Mayer, and Case 1997; Bogart and Cromwell 1997; Hayes and Taylor 1996; Haurin and Brasington 1996). The question of how changes in school characteristics relate to changes in real estate values remains open in part because, as Mieszkowski and Zodrow (1989) note, many of the existing efforts to determine the extent of capitalization have been flawed because inadequate data were utilized. Such data problems may explain why it is rare that school characteristics are included in models of house prices. First, it is far from clear which attributes of local schools individuals consider when deciding on where to buy a house. While in the education production literature a variety of measures of school quality have been considered (see the papers in Burtless 1996), there is no reason to believe that any of these measures of school quality are the ones on which homeowners rely. Second, obtaining data on school attributes at a disaggregate enough level to be useful in a house price analysis is difficult.

Bradbury, Mayer, and Case (1997) and Bogart and Cromwell (1997) respond to these criticisms of earlier research by choosing contexts that permit the construction of data sets free of many of the flaws of data used in the earlier research. Bradbury, Mayer, and Case develop measures of the extent of capitalization of school quality from a regression model in which the dependent variable is the change in house price indices for communities in Massachusetts, calculated using the weighted repeat sales methodology. Bogart and Cromwell take advantage of institutional anomalies in the Cleveland area to assemble a data set that allows them to use a decomposition methodology to estimate the value of good schools.

Each of these papers represents a significant advance over the existing literature. However, there are several reasons to doubt whether even their measures of capitalization are accurate. First, as Kiel and Zabel (1997) show, house price indices calculated using the repeat sales methodology can be systematically biased because they are based on a non-random sample of houses. Second, in the case of Bradbury, Mayer, and Case, while they are able to control for inter-jurisdictional variation in changes in school quality, they do not account for intra-jurisdictional variation in changes in quality. Since a number of recent studies (e.g., Downes and Horowitz 1995) indicate that intra-jurisdictional variation in the attributes of local schools (both in levels and in changes) can be large, failing to control for this variation could result in incorrect estimates of the extent of capitalization. Finally, in neither paper are the authors able to fully account for neighborhood quality. Bradbury, Mayer, and Case use cities and towns as their unit of analysis. Cities and towns in Massachusetts can be geographically large and can have populations that are very heterogeneous. As a result, accurate controls for variation in neighborhood characteristics are unavailable. Similarly, Bogart and Cromwell's data do not allow them to fully control for variation in neighborhood characteristics. If, as seems plausible, changes in neighborhood quality are correlated with changes in the attributes of local schools, the absence of controls for neighborhood quality could result in biased estimates of the extent of capitalization.

In this study, we use a unique data set that overcomes these difficulties. We merge data from the metropolitan version of the American Housing Survey (AHS) for Chicago in 1987 and 1991, the Summary Tape Files (STF) from the 1980 and 1990 Decennial Censuses, and the Illinois School Report Cards from 1987-88 through 1991-92 to create a data set of house values and owner, structural, and neighborhood characteristics (including school characteristics) by census tract. Because of a special relationship with the Census Bureau, we are able to merge the Census and AHS data by census tract. We then use the Census Bureau's Tiger Line files to determine the census tract in which each school is located and the school district in which each census tract is contained. We assign to each census tract the school-level data for the closest school in the relevant school district.

This rich data set allows us to address a number of questions. First, are the neighborhood proxies in the STF correlated with school characteristics and, if so, does the exclusion of the neighborhood variables significantly bias the estimates of the coefficients on the school characteristics in house price regressions? Second, is school quality capitalized in house prices? Third, if so, does the extent of capitalization depend on the measure of school quality that is used?

Fourth, what prices do people place on different school characteristics? Fifth, do these prices differ if the schooling information is allowed to vary within districts as well as across school districts?

The paper is organized as follows. Section II includes a literature review of the impact of school characteristics on house prices. We also provide a brief discussion of the literature on the measurement of school quality. In Section III, we develop the models that are the basis for determining the impact of school characteristics on house values. The various data sources are detailed in Section IV and the empirical analysis is presented in Section V. We find that the neighborhood characteristics are highly correlated with school characteristics, and the coefficient estimates for the latter variables are biased if the neighborhood characteristics are excluded. With both the district-level and the school-level data, we find that both per-pupil expenditures and test scores have significant and similar impacts on house values. However, unlike the district-level results, the school-level results support the conclusion that individuals are very sensitive to the racial composition of schools when choosing a home. Thus, it seems important to control for the intra-district heterogeneity in school characteristics. We provide conclusions and areas for future research in Section VI.

II. School characteristics and house prices: A brief review of the literature

The use of hedonic regressions of housing prices on school characteristics dates from Oates' (1969) seminal paper. Using data on per pupil expenditures and average house values in 53 northern New Jersey municipalities, Oates documented a positive relationship between school expenditures and house values. He interpreted this result as evidence in support of Tiebout's

(1956) assertion that individuals make their residential location decisions in response to inter- or intra-jurisdictional differences in taxes and public services provision, an interpretation which has since been widely criticized.[1] Nevertheless, in the aftermath of Oates' work, a number of researchers have estimated similar relationships, typically using a better methodology or improved data. Most of these studies have produced findings similar to those of Oates. What follows in this section is a brief review of selected papers that examine the relationship between house prices and school characteristics.

Dubin and Goodman (1982) estimated the impact of school characteristics and crime measures on 1,765 house prices in Baltimore in 1978. While the norm in the literature had been to use either per pupil expenditures or test scores as the measure of school quality, Dubin and Goodman took a more agnostic approach. They considered 21 elementary school district-level measures of school characteristics such as the pupil-to-staff ratio, average teacher experience, the percent of staff with masters degrees or above, and a battery of third and fifth grade test scores. Because they believed that the school variables were highly correlated, Dubin and Goodman used principle components analysis. While they found that a number of the principle components were related to house prices, the fact that these principle components were based on so many school variables makes it difficult to determine which school characteristics had a significant effect on house prices.

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[1]In fact, a number of authors have noted that if the assumptions of the Tiebout model hold, in equilibrium there will be no relationship between public service levels and land prices. See Lang and Jian (1996) for further discussion of this issue. For discussion of other criticisms of Oates' approach, see Mieszkowski and Zodrow (1989).

Bradbury, Mayer, and Case (1997) used repeat sales analysis to look at the relationship between changes in school quality and changes in house prices in 208 cities and towns in Massachusetts. Since the period they considered post-dated Proposition 2½, the levy limit established by this initiative constrained spending levels to be below the optimum for many of the cities and towns. Bradbury, Mayer, and Case hypothesized that, when such constraints were present, not all changes in public sector spending were capitalized. They argued that only those changes that moved a constrained community closer to its desired level of spending would be reflected in house prices. To test this hypothesis, they regressed the percent changes in house prices between 1990 and 1994 for these 208 cities and towns on the change in per-pupil operating spending relative to the optimum level of spending, the combined test score in 1990, the change in per capita non-school spending relative to the optimum, and demographic and location variables. Since school and non-school spending were endogenous, Bradbury, Mayer, and Case instrumented for these variables. Both school quality measures were significant, and the results were consistent with the hypothesis that only changes in spending relative to the optimum mattered.

Finally, recent work of Bogart and Cromwell (1997) suggests that accurate estimates of the value of good schools can only be produced if adequate controls for neighborhood quality are included. In their study, Bogart and Cromwell consider the sales prices of houses in regions in the Cleveland area that extend across school district boundaries but otherwise have uniform taxes and public services. By comparing the sales prices of houses on either side of the school district boundary, they develop estimates of the value of better schools. However, their data do not allow Bogart and Cromwell to determine which specific attributes of schools consumers value. Further, while the areas they consider are contiguous, Bogart and Cromwell cannot rule out the possibility that some of the sales price variation is attributable to differences in neighborhood quality rather than to differences in school quality. In fact, in separate regressions, they show that up to 7.5 percent of the sales price variation could be attributable to neighborhood quality variation.

For the reasons noted in the introduction to this paper, one of our goals is to build a data set that will allow us to correct some of the potential weaknesses of these recent studies. In addition, we hope to provide a clearer indication of the appropriate measures of school quality to include in a hedonic regression. The previous literature fails to provide a clear-cut choice between potential measures of school quality. Some authors (e.g., Oates 1969) used schooling inputs, like per pupil spending or the pupil-teacher ratio, to measure school quality. Other authors (e.g., Haurin and Brasington 1996) chose to utilize schooling outcomes, typically standardized test scores, to control for school quality. This second approach appears to be more consistent with the results of the voluminous education production literature that is summarized in Hanushek (1986), Hanushek, et al (1994), and Betts (1995). For example, Hanushek (1986) argued that there is no compelling evidence that, *ceteris paribus*, variation in schooling outcomes is related to variation in measured schooling inputs. In addition, he cited several papers that document a link between standardized test performance and labor market outcomes. However, Hanushek also made a compelling case for value-added, or the change over time in a particular cohort's performance on a standardized test, as the appropriate indicator of school quality. Thus, an appeal to the education production literature would lead a researcher to use a value-added measure to control for school quality in a hedonic regression.

What this argument, and much of the existing literature, ignores, is that what should be included in the hedonic regression is the information on local schools that purchasers use when making their location decisions. The information used will depend on the information available to the purchasers and on the purchasers' perceptions of what factors determine school quality. A number of authors (e.g., Lankford and Wyckoff 1992; Downes 1993; Downes and Greenstein 1996) have shown that the share of students attending private schools depends more strongly on variation in public school input levels and the racial/ethnic compositions of public schools than on variation in performance on standardized tests.[2] These results could indicate that families making schooling choices incorrectly perceive that input variation is related to outcome variation. Alternatively, since, in many states, statewide school report cards are a recent phenomenon, this evidence could simply indicate that the information available to those choosing where to live and whether to attend public school was limited to input levels and racial/ethnic composition. Whatever the truth is, the lesson from this research is that choosing the school characteristics to be included in a hedonic regression can only be done empirically. Further, researchers must be sensitive to the fact that, as more information on the attributes of local schools becomes available to home buyers, the structure of the hedonic is likely to change.

Recent work by Hayes and Taylor (1996) comes closest to coming to terms both with the appropriate level of disaggregation of school quality measures and with the possibility that homebuyers and researchers measure school quality in different ways. Hayes and Taylor combined information on the characteristics and sales prices of 288 properties in Dallas in July

[2]Recent work by Lankford and Wyckoff (1997) extends this result to the choice of residential location by families with children.

1987 with data on spending and student performance at the corresponding neighborhood schools within the Dallas Independent School District. They found that, while sales prices were related to two alternative measures of the achievement of students in the neighborhood school, there was no significant relationship between sales prices and per-pupil expenditures in the school. On the basis of these results, Hayes and Taylor concluded that homebuyers and researchers measure school quality in the same manner. However, because they only considered schools within a single school district, variation in per pupil spending was limited, as is the norm within districts (Steifel and Berne 1996). To conclusively determine which school characteristics influence homebuyers' perceptions of school quality, inter- and intra-district variation in school characteristics is necessary.

III. House value models

Assume that the log of the value of house i at time t, $\ln(P_{it})$, is a linear function of house characteristics H_{it}, school characteristics, S_{it}, and other neighborhood characteristics N_{it}. This model is expressed as

$$\ln(P_{it}) = \beta_{0t} + H_{it}\beta_1 + S_{it}\beta_2 + N_{it}\beta_3 + u_i + \epsilon_{it} \quad i=1,...N,\ t=1,...,T, \tag{1}$$

where H_{it}, N_{it}, and S_{it} are lxk_1, lxk_2, and $1xk_3$ vectors of observable regressors, and β_{0t}, β_1, β_2, and β_3 are 1x1, k_1x1, k_2x1, and k_3x1 unknown parameters, and u_i and ϵ_{it} are unobservable stochastic random variables. The parameters in equation (1) can be interpreted as the prices people are willing to pay for the given house characteristics (Rosen 1974). It is quite difficult to get accurate measures of both school characteristics and other neighborhood characteristics at a disaggregated enough level to provide accurate measures of school and neighborhood attributes to use with house-level data. One interesting question to answer is how the coefficients for S_{it} and N_{it} are affected when the other characteristic vector is excluded. This will give some indication of the excluded-variable bias that exists in studies that only include school or neighborhood characteristics.

One problem with equation (1) is that the unobserved individual component (u_i) may be correlated with the observed regressors. Factors determining neighborhood quality, like local park space, accessibility to local services, and block-by-block differences in maintenance, are unlikely to be among the observed neighborhood characteristics. Many of these factors are relatively constant over time and hence are part of the time-invariant error term u_i. Since these factors are likely to be correlated with observed house and neighborhood characteristics, the coefficients for these latter variables will probably be biased. One method for alleviating this bias is to difference the data. This results in the following specification:

$$\Delta \ln(P_{it}) = \Delta\beta_{0t} + \Delta H_{it}\beta_1 + \Delta S_{it}\beta_2 + \Delta N_{it}\beta_3 + \Delta\epsilon_{it} \qquad i=1,...N,\ t=2,...,T. \qquad (2)$$

A modification to the basic model is suggested by the literature on school quality. As discussed in Section II, many researchers argue that the appropriate measure of school quality is value-added; that is, the cross-time change in test scores for students in a particular cohort. The value-added model is specified as

$$\ln(P_{it}) = \beta_{0t} + H_{it}\beta_1 + S_{it}\beta_2 + T_{2it}\beta_{21} + T_{1i,t-j}\beta_{22} + N_{it}\beta_3 + v_i + \epsilon_{it} \quad i=1,...N,\ t=1,...,T, \quad (3)$$

where T_{2it} and $T_{1i,t-j}$ are test scores taken by the same cohort at different grade levels, S_{it} now includes all other school characteristics, and $v_i = u_i - T_{1i,t-j}\beta_{22}$. In the results that follow, we let T_{2it} be eighth grade scores in 1992 and $T_{1i,t-j}$ be sixth grade scores in 1990. Ideally, $T_{1i,t-j}$ will control for the specific students taking the exam in period t-j and T_{2it} will measure the increase in test scores for the identical cohort j years later. Realistically, within a district, the groups taking the exams in periods t-j and t will not be identical but should be similar enough (given the two year gap) that this will be a reasonably accurate measure of value-added.[3] Given the richness of our data, we estimate all three models using the district-level data and the first two models using the school-level data and compare the results in Section V.

IV. Data

In order to address the methodological concerns raised in the previous section, we combined data from several disparate sources. The main data source used for this study is the Metropolitan Statistical Area (MSA) American Housing Survey (AHS). Beginning in 1974, the AHS contains detailed information on particular houses through time that includes the current

[3]Whether the mean score of a district's sixth graders provides a reasonable control for the ability of the same district's eighth graders two years later is an empirical question. Nevertheless, we can think of at least two reasons why it is likely that compositional changes will not result in the sixth grade score being a flawed measure of ability. The Tiebout model would lead us to expect that out-migrants and in-migrants are likely to be very similar. Further, in a two year period, the extent of turnover in a district is likely to be small. These arguments are far less compelling at the school level. For that reason, we chose not to estimate the value-added model using the school-level data.

owner's evaluation of the house price, house characteristics, and self-reported information on the house's current occupants. The AHS surveys a given MSA every three to four years. The 1987 and 1991 interview years of the Chicago MSA are used for this study. Since the AHS includes house values for a random sample of houses rather than a sample that is limited to houses that sold, we are able to avoid the selection bias problems inherent in work that utilizes sales price data.[4]

A house from the AHS was included in the sample only if there was a regular occupant interviewed and if the unit was owner-occupied and sat on a lot of less than ten acres. Because of possible miscodings, houses that sold within twelve months prior to the interview were dropped if the owner's valuation was more than 200% or less than 50% of the sales price.

An important component of house values that is not well quantified in the AHS is information relating to neighborhood quality, as the survey focuses on the occupant's evaluation of a self-defined neighborhood (Kiel and Zabel 1997). However, detailed information on neighborhood characteristics is available in the Summary Tape Files (STF) of the Decennial Censuses. The STF provides summary information for different geographical units including census tracts and sample data that are weighted to represent the total population. The tract

[4]For each house in a given survey year of the AHS, owners are asked for their valuation of their homes. Since this is not the selling price of the house, it is important to know if the reported values can be used as proxies for prices. Goodman and Ittner (1992) and Kiel and Zabel (1996b) study the AHS and find that the average owner overvalues his or her house by approximately 5%. This difference is not related to house, market, neighborhood, or owner characteristics, though, in light of Kiel and Zabel's finding that over-valuation is inversely related to length of tenure, inclusion of a tenure variable in an hedonic regression is mandatory if biases are to be avoided. If such a variable is included, using owners' valuations in equations (1) - (3) only biases the constant term, β_{0t}, and not the coefficients of the determinants in the house value model, β_1, β_2, and β_3.

information includes the median age, the proportion of individuals aged 25 or older who have graduated from high school, average household income, and residential property vacancy rates.

Two other neighborhood characteristic that we utilize are the straight-line distance from the center of each census tract to downtown Chicago and a measure of air quality, both of which have been shown to be significant determinants of house prices (Haurin and Brasington 1996, Smith and Huang 1995) and both of which could be correlated with school characteristics. As our measure of air quality, we use the level of total suspended particulate (TSP), which we obtain from the U.S. Environmental Protection Agency's Aerometric Information Retrieval System (AIRS). The measure used for TSP is the second daily maximum hourly reading, which is related to the National Ambient Air Quality Standard for this pollutant.

To merge these data with the AHS, it is necessary to have information on the location of each house. The internal AHS files identify the census tract in which each house is located. Through special arrangements, we had access to these proprietary data. A census tract is defined as a homogeneous area in regards to the characteristics of the population, their economic status, and living conditions. A tract generally has between 2,500 and 8,000 residents. Knowing in which census tract the house is located allows for more accurate neighborhood characteristics to be assigned to each house.

For data on schools in the Chicago metropolitan area, we turned to Illinois State Department of Education school report cards for 1987-1988 through 1991-1992. For each school in the metropolitan area, the report cards provide information for each school year on the racial and ethnic composition of the school's student population, student performance on the component tests of the ACT, and mean student performance of third, sixth, and eighth graders on the reading and mathematics components of the Illinois Goals Assessment Program (IGAP) tests. In addition, the report cards provide data on expenditures, staffing, and average salaries for each district in Illinois.

These data were augmented with data on assessed values and nominal property tax rates for each district, compiled by the Illinois Department of Revenue.[5] For several reasons, the estimated relationship between house values and this latter variable must be interpreted with caution. First, as Yinger, Bloom, Börsch-Supan, and Ladd (1988) make clear, the capitalization equation should include the effective property tax rate. We lack the data to construct effective property tax rates.[6] Second, the full nominal tax rate on any property is the sum of the tax rate for schools and the tax rates for all other overlapping jurisdictions. Thus, a school tax rate that is high need not be associated with a high overall nominal tax rate. Still, given available data, the school tax rate is the best indicator of interjurisdictional variation in effective tax rates.

To assign each house in the AHS to a selected school, we started with the school addresses in the Report Card data. Then, using the U.S. Census Tract/Street Index data base, we assigned each school to a census tract.[7] We then matched each house with the nearest school in

[5]Thanks to Richard Dye for making these data available to us.

[6]Actually, we are able to include one crude control for variation in effective tax rates. By law, Cook County has lower assessed-to-market value ratios on residential property than do the other counties in the Chicago MSA. Thus, we include a dummy variable to account for a house being located in Cook County.

[7]Since the Census Tract/Street Index data does not provide complete coverage, the assignment of schools to census tracts was completed using county-level maps created from the Tiger Line files.

the school district that served students of a particular grade level.[8] If a house was in a tract that was divided between two or more school districts, we matched this house to a school in each district in which the house could be located. We then averaged the data from each of these matches using the fraction of the tract located in each school district as weights.

V. Empirical results

In this section, we provide the results from our empirical analysis of the impact of school characteristics on house values. However, before considering estimates of the models developed in Section III, we present evidence on a question raised at the outset: Are neighborhood characteristics correlated with the characteristics and performance of the students? The regression analysis that then follows consists of two parts. Initially, we present results using the district-level measures of the attributes of the schools.[9] This is the typical level of aggregation used in most analyses of the link between house values and school characteristics. We then present regression results using the school-level data. By comparing these results to those based on the district-level data, we can see if capturing the intra-district heterogeneity in school characteristics has a significant impact on the coefficient estimates for the school characteristics.

Table 1 contains the definitions and summary statistics for the variables used in this analysis. The neighborhood characteristics include the log of median household income

[8]If multiple schools in a census tract served students of a particular grade level, the data for these schools were averaged using relative enrollments as weights.

[9]Within the City of Chicago, we created artificial "sub-districts" and assigned to each house the school characteristics for the sub-district in which the house was located. The boundaries of the sub-districts corresponded to the boundaries of the 76 community areas into which the City of Chicago is divided.

(LNMEDI), median age (MEDAGE), the proportion nonwhite (PROPNW), the proportion over 25 who graduated from high school (PROPHS), the proportion of blue collar workers (PROPBC), the proportion of houses that changed hands in the last five years (PROPCH5), the proportion of vacant houses (PROPVAC), and the proportion of houses with less than one occupant per room (PROPLO). These measures of neighborhood quality are proxies for the crime rate and other factors that are considered to be important to homeowners.[10] To obtain neighborhood characteristic variables for 1987, we interpolate using the 1980 and 1990 values of the variables. We use the 1990 values for the 1991 AHS survey.

The school characteristics include two measures of racial/ethnic composition, the proportion of students who are African-American (AFRAM) and the proportion of students who are Hispanic or Native American (HISPNA), and two variables that have been shown to be correlated with the cost of education, the proportion of students who are limited English proficient (LEP) and the proportion of students who receive school lunch subsidies (LOWINC). We include the log of per pupil expenditures (LNPPEX) to measure school expenditures, and we use the log of third (LNRDG3), sixth (LNRDG6), and eighth (LNRDG8) grade IGAP reading scores to measure student performance. The results we present are for LNRDG8. Similar results entail for LNRDG3.[11]

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[10]Palmquist (1982, 1984) and Kiel and Zabel (1996a, 1996b, 1997) find that there are highly significant when included in hedonic house value regressions.

[11]We have also estimated all of the specifications presented below with eighth grade IGAP mathematics scores substituted for the reading scores. Since the results were qualitatively the same when mathematics scores were used, in the interest of brevity, we present only the results for reading scores.

V.I Correlations between the school characteristics and neighborhood variables

Table 2 contains the correlations between the school characteristics and neighborhood variables for the pooled data. There are many correlations that are greater than 0.5, particularly between the reading score variable and the neighborhood characteristics. Thus, it is clear that these two types of variables are highly correlated. We also provide the R^2s from regressions of the school attributes on all the neighborhood characteristics to offer some information on the joint correlation between these variables. Again, a number of the R^2s are greater than 0.5, including those for AFRAM, LOWINC, and LNRDG8, indicating a high correlation between the neighborhood characteristics from the Decennial Census and the school characteristics. It is apparent that, if neighborhood characteristics are capitalized in house prices, excluding the neighborhood indicators will likely bias the coefficients for the school characteristics.

Note that the correlation between reading scores and school expenditures (LNRDG8 and LNPPEX) is quite low, 0.077. Thus, there should be no problems with multicollinearity when both LNRDG8 and LNPPEX are included in the house value regressions.

V.II Estimates of the House Value Models

For purposes of comparison, we give in Table 3 the regression results for the pooled, first-difference, and value-added models when district-level measures of the attributes of the schools are used. In Table 4 we present estimates of variants of the first two of these models when the district-level measures are replaced with school-level measures.[12] In addition to the neighborhood

[12]The F-statistic for the test that the coefficients for 1987 and 1991 are equal for the specification in the second column of Table 4 is 0.79, with 29 numerator and 2068 denominator degrees of freedom. Thus, we cannot reject the pooled specification.

and school characteristics, we include a number of house characteristics (CC, HAGE, HAGE2, GAR, BEDS, FBTH, and AC), a property tax rate variable (LNTAX), dummy variables for length of tenure (TENURE, TEN15, and TEN510), a dummy variable (D91) to account for house value appreciation between 1987 and 1991, and a dummy variable (COOK) to account for a house being located in Cook County.

Because local public spending decisions and residential location decisions could be simultaneously determined, LNTAX, LNPPEX, and LNRDG8 are assumed to be endogenous. We use the proportion of the tax base that is residential (PROPRES), per pupil assessed value (EAV), the proportion renting (PROPRENT), and the proportion of the population that is school aged (PROPSCAG) as instruments. We assume that these variables are valid instruments because they represent demand-side factors that influence the level of school inputs and outcomes but do not directly affect house prices.

In all of the specifications in Tables 3 and 4, the estimated coefficients for the house characteristics are generally significant with the correct sign. The estimates of the coefficient on D91 indicate that house prices appreciated between 12 percent and 16 percent from 1987 to 1991. Surprisingly, given the differences in assessment practices, we find no evidence that house prices in Cook County were higher, holding all else equal.

Since one of the main conclusions of this paper is that hedonic regressions that use school-level measures of school attributes capture the extent of capitalization more accurately than regressions that use district-level data, expansive discussion of the results in Table 3 is not warranted. However, for reasons noted above, we are not comfortable estimating the value-added specification using the school-level data available to us. Unfortunately, if homeowners use as their measure of school quality the academic improvement of a cohort of students in a community's schools, our estimates of the extent of capitalization derived from the school-level data will be biased. While, for the school-level data, we cannot reject the value-added specification, we can use the district-level data to begin to explore the appropriateness of this model of house prices.

The estimates in the final column of Table 3 support the conclusion that homeowners do not consider the extent to which a community's schools contribute to a cohort's test performance, holding constant the current test performance of that cohort. The estimated coefficient on the mean test score two years earlier of sixth graders in the district does not differ significantly from zero.[13] Further, the implied effects of the remaining variables are essentially the same as the effects implied by the pooled regression results in the second column.

That we conclude that homeowners do not measure school quality in the same way as researchers is not surprising, given the information real estate firms make available to prospective purchasers.[14] In addition, though Hayes and Taylor (1996) argued that homebuyers and researchers measure quality in the same way, the parameter estimates in their paper appear to be

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[13]The relevant portion of equation (3) can be rewritten as

$$T_{2it}(\beta_{21} + \beta_{22}) - (T_{2it} - T_{1i,t-j})\beta_{22} .$$

Thus, if consumers base their evaluations of school quality on value-added rather than current performance, β_{22} would differ significantly from zero and β_{22} would equal β_{21} in absolute value. Instead, we find β_{22} is insignificantly different from zero.

[14]For an example of the type of information that is readily-available to a prospective homebuyer, see the State of Arizona's Department of Education web site (URL: http://www.ade.state.az.us/reportcards/).

consistent with the hypothesis that homebuyers' evaluations of neighborhood schools are based on the mean contemporaneous test scores and not on the value-added produced by those schools.

Turning to Table 4, we first present estimates of the pooled regression without the neighborhood quality variables. The estimated coefficient for LNTAX is significant but has the wrong sign. While this result is troubling, for the reasons noted above, we do not feel it supports the conclusion that higher effective property tax rates are not associated with lower property values. Further, a finding of a positive relationship between house values and the nominal property tax rate is not unusual; Haurin and Brasington (1996) generate a similar result in their study of house price determination in Ohio.

As expected, the coefficients on the racial composition variables (AFRAM and HISPNA) are negative and significant, as is the coefficient on one of the school cost variables, the proportion of students eligible for subsidized lunch (LOWINC). The other cost variable (LEP) is also significant, but surprisingly increases in LEP are associated with higher house prices. Finally, both of the direct measures of school quality have positive and significant coefficients. The estimated coefficient on the eighth grade reading score variable (LNRDG8) implies that a 1 percent increase in the mean reading test score in the neighborhood school will lead to a 1.6 percent increase in house values, on average. A 1 percent increase in per pupil expenditures in the school district will result in an increase in house values of 0.67 percent, on average.

While inclusion of the neighborhood characteristics fails to change the direction of any of the relationships between school characteristics and house prices, this modification reduces the absolute magnitude of all of the coefficient estimates on the school characteristics. The proportion of students eligible for subsidized lunch (LOWINC) is no longer a significant determinant of house prices. The elasticity of house prices with respect to reading scores falls from 1.6 to 0.7; the elasticity with respect to per pupil expenditures falls from 0.67 to 0.39. It appears that when the neighborhood characteristics are excluded, the school quality measures are biased upward due to the high correlation between the two groups of variables. Nevertheless, these estimates support the conclusion that homeowners consider both the input and output levels of schools when deciding where to live. The contrast between this result and the results of Hayes and Taylor (1996) suggests that accurate estimates of the extent of capitalization require both inter- and intra-district variation.

For the pooled regression, the estimated effects of those neighborhood characteristics that are significantly related to house prices are generally consistent with expectations. In particular, it is noteworthy that house prices are lower in census tracts with poorer air quality.

The first-difference results generally confirm that inclusion of a rich set of house and neighborhood characteristics eliminates the need to also control for temporally-stable, unobserved house and neighborhood characteristics which, if omitted, could bias the estimated prices of school characteristics. Specifically, the estimated effects of changes in mean reading scores (LNRDG8) and per pupil expenditures (LNPPEX) are essentially the same in the second and third columns of Table 4. That the signs and magnitudes of the estimated coefficients on the two school cost variables are different in the pooled and the first-difference specifications is unsurprising, in light of Downes and Pogue's (1994) conclusion that temporally-stable determinants of schooling costs are correlated with measured determinants of cost.

As the above discussion implies, the estimates of our preferred specification of the house price model are in the second column of Table 4. Comparison of these results to those in the second column of Table 3 reveals the biases associated with failing to consider data disaggregated to the school-level. First, the change in the coefficient on the proportion of students who are African-American (AFRAM) is evidence that individuals are concerned about the racial composition of the local school. This sensitivity to race is not revealed when district-level measures are used. Second, the implied effects of both of the school cost variables (LEP and LOWINC) are significantly muted when the district-level measures are replaced by the school-level measures. Finally, the estimated prices of the direct measures of school quality (LNRDG8 and LNPPEX) do not seem to depend on whether school- or district-level data are used. While this result strengthens the argument that the measures of school quality that homeowners use are different from the measures used by researchers, this result does not obviate the need to utilize school-level measures.

The final column of Table 4 includes estimates that allow us to test a proposition suggested in Section II; changes over time in the information available to homeowners may have changed the relative importance of different attributes of the local schools. Specifically, as states have made more of an effort to publicize school report cards and as more attention has been paid to the ability of schools to meet statewide standards, we would expect that the relationship between house prices and standardized test scores should strengthen. While, formally, the estimates in Table 4 do not allow us to reject the null hypothesis that the relationship between house prices and eighth grade test scores is temporally stable, the direction of change of the estimates is consistent with the proposition. Further, the possible validity of the proposition is strengthened by the fact that the relationship between per pupil spending and house prices is remarkably stable over time.

VI. Conclusions

We have estimated the impact of school characteristics on house values in Chicago for 1987 and 1991 using a unique data set that permits us to avoid many of the problems that plague previous analyses. Our results indicate that individuals pay attention to both per-pupil expenditures and test scores when deciding where to locate. However, when purchasing a home, individuals do appear to consider the current test performance of students in the local school rather than the extent to which a community's schools contribute to a cohort's test performance.

Our results also suggest that, if district-level measures of school attributes are used instead of school-level measures, significant biases in the estimated effects of school characteristics can result. Specifically, when district-level data are used, the resulting estimates tend to understate the sensitivity of homeowners to the racial composition of the local schools. We also find that it is necessary to include measures of neighborhood quality in addition to the school characteristics. Excluding relevant neighborhood characteristics biases the coefficient estimates for the school characteristics.

Finally, our findings suggest that it might be fruitful in future work to explore the possibility that the coefficients on the school quality variables vary across time. As indicated in Section II, changes in the political climate in which schools operated (and are operating) changed the information that homeowners have on school quality. We provide preliminary evidence in support of this proposition, but continued work on the relationship between changes in the political climate and the weight prospective homeowners placed on particular measures of school quality is warranted.

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Table 1
Variable Names, Definitions, and Summary Statistics

Variable	Definition	Mean	Std Dev
LNVALUE	natural log of owner-estimated house value	11.528	
CENCITY	=1 if house in central city of SMSA, =0 otherwise	0.2452	0.4303
HAGE	the age of the house in years	37.1953	18.8920
HAGESQ/100	the square of the age of the house in years/100	17.4023	16.6371
GARAGE	=1 if the house has a garage, =0 otherwise	0.8872	0.3164
BEDROOMS	number of bedrooms in the house	3.1641	0.8858
FULLBATHS	number of full bathrooms in the house	1.5534	0.7953
AIRCOND	=1 if the house has either central or room air conditioning, =0 otherwise	0.8583	0.3488
LNMEDI	natural log of median income in the house's census tract in tens of thousands of 1990 dollars	10.6898	0.3279
MEDAGE	median age of individuals in the house's census tract	31.8145	5.2100
PROPNW	proportion of nonwhite individuals in the census tract	0.1976	0.2886
PROPHS	proportion of individuals over 25 who have completed high school in the census tract	0.7856	0.1246
PROPBC	proportion of blue-collar workers in the census tract	0.3595	0.1319
PROPCH5	proportion of houses in the census tract that have changed hands in the last five years	0.4388	0.1418
PROPVAC	proportion of housing units vacant in the census tract	0.0416	0.0325
PROPLO	proportion of houses in the census tract with less than one occupant per room	0.9669	0.0409

TSP	second daily maximum hourly reading of total suspended particulate in micrograms per cubic meter	113.7949	23.8245
TENURE	=1 the the household moved into the unit in the 12 months prior to survey, =0 otherwise	0.0839	0.2773
TENURE15	=1 if household in unit 1 to 5 years, =0 otherwise	0.2289	0.4202
TENURE510	=1 if household in unit 5 to 10 years, =0 otherwise	0.2252	0.4178
D91	=1 if 1991, =0 if 1987	0.5569	0.4968
COOK	=1 if in Cook County, =0 otherwise	0.6797	0.4666
CBD	distance (in miles) from the center of the census tract to downtown Chicago	17.7743	9.2620
AFRAM	proportion of students in school/district who are African-American	0.2090	0.3037
HISPNA	proportion of students in school/district who are hispanic or Native American	0.1070	0.1569
LEP	proportion of students in school/district with limited english proficiency	0.0469	0.0724
LOWINC	proportion of students in school/district who are eligible for subsidized school lunches	0.2473	0.2881
LNPPEX	natural log of district-level per pupil expenditures	8.4647	0.2262
LNRDG8	natural log of average school/district eighth grade reading component of the IGAP tests	5.5402	0.1402
TAXRT	nominal property tax rate	4.7614	0.8544
EAV	per-pupil assessed value	103563	75273
PROPRES	proportion of total assessed value that is residential	0.5402	0.1960
PROPRENT	proportion of rental units	0.3292	0.1719
PROPSCAGE	proportion of population that is school aged	0.2768	0.0349

Table 2
Correlations for School and Neighborhood Variables

	AFRAM	HISPNA	LEP	LOWINC	LNPPEX	LNRDG8
			School Variables			
HISPNA	-0.11821					
LEP	-0.14671	0.78354				
LOWINC	0.67448	0.48695	0.41443			
LNPPEX	0.02464	0.03912	0.13385	0.10487		
LNRDG8	-0.57977	-0.43618	-0.35096	-0.77894	0.13400	
			Neighborhood Variables			
LNMEDI	-0.45871	-0.37765	-0.30270	-0.62248	0.28332	0.69865
MEDAGE	-0.16769	-0.16196	-0.04804	-0.19561	0.36280	0.28790
PROPNW	0.83653	0.05009	0.02744	0.66632	0.05584	-0.56296
PROPHS	-0.37721	-0.55603	-0.45926	-0.68742	0.10963	0.70637
PROPBC	0.27575	0.47038	0.35071	0.52690	-0.31747	-0.65712
PROPCH5	-0.26498	0.03188	0.04049	-0.24383	-0.26341	0.12793
PROPVAC	0.25569	0.12907	0.07629	0.32532	-0.09065	-0.31571
PROPLO	-0.36489	-0.44876	-0.38955	-0.55804	0.00120	0.52570
TSP	0.28984	0.06025	0.05072	0.31862	0.11338	-0.16502
CBD	-0.29755	-0.17396	-0.22900	-0.39596	-0.41030	0.23301
			R^2 from Regression on Neighborhood Variables			
R^2	0.7486	0.4164	0.3318	0.6589	0.4021	0.6135

Table 3
Regressions Using District-Level Measures of School Quality[1,2]
Dependent Variable: Natural Log of Owner-Estimated House Value (LNVAL)
(Standard Errors in Parentheses)

Independent Variable	Pooled Regression- Neighborhood Variables Excluded	Pooled Regression- Neighborhood Variables Included	First- Differenced Regression	Value-Added Regression
LNTAX	1.0077** (0.2899)	0.6623** (0.2984)	0.4639 (0.4288)	0.4735* (0.2467)
AFRAM	-0.0550 (0.0885)	0.0246 (0.1141)	-0.3078 (0.5475)	0.1758 (0.1703)
HISPNA	-0.5546** (0.1852)	-0.5390** (0.1800)	-0.2054 (0.6469)	-0.3564 (0.2595)
LEP	2.1758** (0.3301)	1.9272** (0.3278)	-0.6787 (0.8508)	1.9985** (0.4511)
LOWINC	-0.7733** (0.3751)	-0.4484** (0.1268)	-0.0101 (0.3688)	-0.5648** (0.2170)
LNPPEX	0.6959** (0.1265)	0.4475** (0.1334)	0.6081 (0.6096)	0.6764** (0.2153)
LNRDG8	1.4822** (0.2787)	0.7023** (0.3068)	0.1969 (0.3442)	0.6542* (0.3432)
LNRDG690				0.0937 (0.2720)
CBD		-0.0047** (0.0023)		-0.0048 (0.0033)
TSP		-0.0011** (0.0005)	0.0012* (0.0007)	-0.0015 (0.0020)
LNMEDI		0.2722* (0.0759)	0.6012 (0.8417)	0.3284** (0.1123)
MEDAGE		0.0032 (0.0034)	0.0016 (0.0203)	0.0020 (0.0047)
PROPNW		-0.2055** (0.0864)	-0.4503 (0.8797)	-0.3207** (0.1283)
PROPHS		-0.0071 (0.2661)	1.7619 (1.5825)	-0.1038 (0.3869)

Table 3 - Continued

Independent Variable	Pooled Regression-Neighborhood Variables Excluded	Pooled Regression-Neighborhood Variables Included	First-Differenced Regression	Value-Added Regression
PROPBC		-0.6258** (0.2501)	3.8512** (1.2880)	-0.5919* (0.3551)
PROPCH5		0.1236 (0.1256)	1.0188 (0.6657)	0.1192 (0.1720)
PROPVAC		-0.0045 (0.4613)	1.4738 (2.5267)	0.4662 (0.6322)
PROPLO		-1.0759** (0.4767)	-1.7987 (2.4839)	-0.9495 (0.6509)
R^2	0.3612	0.4353	0.0413	0.4142
Number of Observations	2128	2128	753	1185

* - Significant at 10 percent level.
** - Significant at 5 percent level.

Notes: 1. Each equation is estimated using two-stage least squares. The endogenous variables are the natural log of the nominal tax rate (LNTAX), the natural log of per pupil expenditures (LNPPEX), and the natural log of the mean score of eighth graders on the IGAP reading test (LNRDG8). Instruments include proportion of the tax base that is residential (PROPRES), per pupil assessed value (EAV), proportion renting (PROPRENT), and proportion of the population that is school age (PROPSCAG).

2. Each regression includes a constant and a set of characteristics of the house (CENCITY, HAGE, HAGESQ/100, GARAGE, BEDROOMS, FULLBATHS, AIRCOND, TENURE, TENURE15, and TENURE510). In addition, except for the first-differenced regression, all of the regressions include dummy variables to indicate if the observation was from 1991 (D91) and if the house was located in Cook County (COOK).

Table 4

Regressions Using School-Level Measures of School Quality[1,2]

Dependent Variable: Natural Log of Owner-Estimated House Value (LNVAL)

(Standard Errors in Parentheses)

Independent Variable	Pooled Regression-Neighborhood Variables Excluded	Pooled Regression-Neighborhood Variables Included	First-Differenced Regression	Pooled Regression-Cross-Time Changes
LNTAX	1.2527** (0.3348)	0.7024** (0.3347)	0.3660 (0.6250)	0.6702** (0.2798)
AFRAM	-0.1981** (0.0829)	-0.1663* (0.1012)	-0.5627 (0.3565)	-0.1877** (0.0957)
HISPNA	-0.4002** (0.1462)	-0.3246** (0.1379)	-0.5998 (0.4753)	-0.3340** (0.1309)
LEP	1.2155** (0.2753)	1.0758** (0.2620)	-0.7530 (0.5414)	1.0780** (0.2489)
LOWINC	-0.4129** (0.1059)	-0.0834 (0.1039)	0.3603 (0.2424)	-0.0476 (0.0994)
LNPPEX (LNPPEX91)	0.6651** (0.1405)	0.3889** (0.1427)	0.3968 (0.9009)	0.4551** (0.1608)
LNRDG8 (LNRDG891)	1.6030** (0.3097)	0.7084** (0.3139)	0.8734 (0.7234)	0.7504** (0.2547)
LNPPEX88				0.4056** (0.1680)
LNRDG888				0.4413 (0.3595)
CBD		-0.0058** (0.0023)		-0.0059** (0.0022)
TSP		-0.0010** (0.0005)	0.0010 (0.0007)	-0.0014** (0.0005)
LNMEDI		0.3011* (0.0753)	0.5750 (0.8512)	0.2989** (0.0723)
MEDAGE		0.0061* (0.0034)	0.0039 (0.0204)	0.0062* (0.0033)
PROPNW		-0.1099 (0.0904)	-0.2386 (0.8658)	-0.1011 (0.0858)

Table 4 - Continued

Independent Variable	Pooled Regression-Neighborhood Variables Excluded	Pooled Regression-Neighborhood Variables Included	First-Differenced Regression	Pooled Regression-Cross-Time Changes
PROPHS		0.2737 (0.2691)	1.7931 (1.5978)	0.3280 (0.2568)
PROPBC		-0.5118** (0.2528)	3.3507** (1.2826)	-0.5183** (0.2403)
PROPCH5		0.1830 (0.1269)	1.0036 (0.6678)	0.1603 (0.1206)
PROPVAC		-0.3750 (0.4552)	1.4400 (2.3112)	-0.2862 (0.4338)
PROPLO		-1.2278** (0.4850)	-1.9036 (2.5420)	-1.2320** (0.4607)
R^2	0.3039	0.4244	0.0294	0.4807
Number of Observations	2126	2126	756	2126

* - Significant at 10 percent level.
** - Significant at 5 percent level.

Notes: 1. Each equation is estimated using two-stage least squares. The endogenous variables are the natural log of the nominal tax rate (LNTAX), the natural log of per pupil expenditures (LNPPEX), and the natural log of the mean score of eighth graders on the IGAP reading test (LNRDG8). Instruments include proportion of the tax base that is residential (PROPRES), per pupil assessed value (EAV), proportion renting (PROPRENT), and proportion of the population that is school age (PROPSCAG).

2. Each regression includes a constant and a set of characteristics of the house (CENCITY, HAGE, HAGESQ/100, GARAGE, BEDROOMS, FULLBATHS, AIRCOND, TENURE, TENURE15, and TENURE510). In addition, except for the first-differenced regression, all of the regressions include dummy variables to indicate if the observation was from 1991 (D91) and if the house was located in Cook County (COOK).