DEPARTMENT OF ECONOMICS WORKING PAPER SERIES

School Choice and the Flight to Private Schools: To What Extent are Public and Private Schools Substitutes?

David M. Brasington
Louisiana State University

Working Paper 2006-04
http://www.bus.lsu.edu/economics/papers/pap06_04.pdf

Department of Economics
Louisiana State University
Baton Rouge, LA 70803-6306
http://www.bus.lsu.edu/economics/

School Choice and the Flight to Private Schools: To What Extent Are Public and Private Schools Substitutes?

David M. Brasington
John C. Hamilton Professor for Developing Scholars
Economics Department
Louisiana State University
Baton Rouge, LA 70803

Phone: (225) 578-7822
Fax: (225) 578-3807
Email: dbrasin@lsu.edu

March 1, 2006

School Choice and the Flight to Private Schools: To What Extent Are Public and Private Schools Substitutes?

Abstract

Opponents of school choice sometimes charge that vouchers, charter schools, and tuition tax credits would strip funding and talented students from the public schools. Proponents say this is exactly what is needed to provide extra competition for public schools. Flight to private schools may happen if parents think private schools are good substitutes for public schools. For goods with explicit market prices, economists estimate substitutability by specifying a demand curve and finding a cross price elasticity, but the non-market nature of schooling has prevented this. The current study finds a way to estimate the demand for public schooling and calculate a cross price elasticity by exploiting Rosen's (1974) two-stage hedonic technique. It estimates the cross price elasticity between public schooling and the price of private schooling to be 0.32: Americans view private schools as fairly weak substitutes for public schools. The use of spatial statistics accounts for potential spillovers and omitted variable bias in the house price hedonics and the demand curve estimation. In fact, the -1.72 price elasticity of demand is much larger than the -0.20 to -0.40 estimates generally found by non-spatial studies.

JEL Classification codes: H41, R21, R22
Keywords: local public goods provision, private school competition, spatial statistics, education vouchers, spillovers

"This was the Super Bowl of school choice, and children won," –Clint Bolick, Vice President of the Institute for Justice, June 27, 2002

"The majority took a wrecking ball today…Vouchers are an unconscionable diversion of resources away from the public schools," –Barry W. Lynn, President of Americans United for Separation of Church and State, June 27, 2002 (Walsh, 2002)

1. Introduction

School choice programs, in the form of charter schools, school vouchers, and tax credits for private school tuition, are becoming more common in the United States. The legislative, executive, and judicial branches of government are all active contributors. For example, The No Child Left Behind Act of 2001 allows students to transfer out of failing schools and recommends converting thousands of failing public schools into charter schools. President Bush's 2003 budget proposed giving families up to $2500 per child in tax credits if they chose a private school rather than a failing public school. And in 2002 the U.S. Supreme Court ruled in *Zelman v Simmons-Harris* that the government may fund vouchers for private, religious schools. What would happen if school choice programs became widespread? Would parents flee to private schools, abandoning the public schools? The idea of 'abandoning the public schools' is broadly defined to mean less public schooling demanded. It means a smaller market share for traditional public schools. It also means less funding for public schools, as money follows students to other schools; and it might mean less frequent passage of tax levies. Abandoning the public schools might also mean greater cream-skimming, in which the most talented students leave the public schools (Epple and Romano, 1998; Epple, Figlio and Romano, 2004). Less money and worse peer effects might reduce public school quality, so 'abandoning the public schools' also implies a lower quality of public schooling demanded. But whether school choice programs like vouchers and tax credits would make parents abandon public schools for private schools is an empirical question. The answer depends on the degree to which parents perceive public and private schools to be substitutes, and it is this substitutability that the current study explores.

The degree to which public and private schools are substitutes has special importance for school voucher programs. Currently in the United States tax money funds public schools, and residents who live in a public school district may send their children to their own public school for no extra charge. If residents want to send their children to a private school or a different public school district, they must continue to pay taxes for their assigned public school and additionally pay full tuition for the school their child attends. School choice programs break the link between houses and public school district assignments. One school choice program is a school voucher. If the assigned public school district spends $7,000 per pupil, one form of school voucher system would give parents a voucher worth $7,000 which may be redeemed at the assigned public school, or it may be used toward tuition at the public or private school of the parents' choice. Some polling suggests that about 60% of Americans favor private school vouchers (Walsh, 2001). The strongest supporters of vouchers are racial minorities and people living in low-income areas with poor quality public schools (Walsh, 2001; Sandy, 1992). Voucher programs have been proposed or enacted in California, Florida, Michigan, Louisiana, Maine, D.C., Colorado, Indianapolis, Milwaukee, San Antonio, Atlanta, Cleveland, Vermont, New Hampshire, New Jersey, and other states and cities throughout the United States (Merrifield, 2002). In 2005 the Arizona senate passed an unrestricted private school voucher bill, and in 2006 Governor Pataki introduced a tax credit for parents in New York who choose private schools.

With the increasing public awareness, it is useful to ask whether school choice will provide competition for public schools. Stronger competitive effects will be seen the more private and public schools are seen as close substitutes. Opponents of vouchers point out that a voucher system may gut public schools, transferring students and their associated funding away from the already cash-strapped public schools toward private schools. This 'mass exodus' argument assumes that private schools are seen as good substitutes for public schools. So in order to better evaluate the likely competitive effects of vouchers and to assess the validity of the mass exodus objection to private school vouchers, it is necessary to estimate the degree to which Americans perceive public and private schools to be substitutes.

Some previous research has investigated the sensitivity of private school enrollment to tuition, and the relationship between public school expenditures and private school enrollment. These studies have provided valuable (but contradictory) insights on the degree to which public and private schooling are substitutes. However, in introductory microeconomics courses, students are taught to measure substitutes and complements from the cross price elasticity of demand. The non-market nature of schooling has prevented researchers from estimating the cross price elasticity of demand. But the current study exploits the theory of implicit markets (Rosen, 1974) to find the price of a unit of public schooling from the housing market. It can then estimate the demand for public schooling to find the cross price elasticity between public and private schooling, to see to what extent Americans view public and private schools as substitutes. If private schools are strong substitutes for public schools, school choice programs may induce an exodus of students and money from public schools to private schools, and scare public schools into providing higher quality service at a lower price (Figlio and Rouse, 2006). If private schools are weak substitutes for public schools, school choice programs might subsidize private—and often religious—schools, increase taxes[1], and fail to provide much additional competition for public schools.

The empirical estimation consists of first estimating a series of house price hedonic regressions, then using the results from the first stage to estimate the demand for public schooling. The estimation technique, spatial statistics, addresses identification and spatial dependence, which may arise from spillovers and omitted variables. Private schooling appears to be a fairly weak substitute for public schooling. The cross price elasticity of demand is 0.32. Furthermore, the cross price elasticity of demand is nearly identical for rich and poor households. The weak cross price elasticity may help explain the low take-up rate on some school choice programs. Only 1097 out of 270,000 eligible students transferred from failing schools in Chicago under the No Child Left Behind Act, and only 215 transferred out of 204,000 eligible in Los Angeles (Helfand and Rubin, 2004).

The study finds the elasticity of house price with respect to public proficiency test scores is 0.15. Own price elasticity of demand for public schooling is -1.72 and the income elasticity of demand is 0.31. The spatial statistical technique makes a large difference in demand parameter estimates such as the price elasticity of demand, the income elasticity of demand, and the role of Catholics and persons with less than a bachelor's degree. Compared to those living in houses with three or fewer bedrooms, people who live in houses with a large number of bedrooms have stronger cross price and income elasticities of demand for public schooling.

2. Previous Literature

Previous studies have estimated the cross price elasticity of demand for competition between public and private universities (Allen and Shen, 1999), but not between public and private elementary and secondary schools. Previous studies have also investigated the price elasticity of demand for private schooling (Chiswick and Koutromanes, 1996; Hoenack, 1997). Others investigate the effect public school expenditures has on private school enrollment (Hamilton and Macauley, 1991; Goldhaber, 1999), and the effect of private school enrollment on public school expenditures (Erekson, 1982; Goldhaber, 1999). Buddin, Cordes and Kirby (1998) regress a family's decision to use private schools as a function of both private school tuition and public school proficiency test scores. But while these studies all provide valuable information about the determinants of the demand for public and private schooling, none has calculated a cross price elasticity between public and private schooling. There is a reason they have not.

3. Analytical Framework

3.1 Rosen's (1974) First Stage House Price Hedonic

A demand function contains the price of the good, the price of related goods, and other demand shifters. Because there is no explicit market, there is no readily observable unit price of public schooling. This lack of data is probably what has kept researchers from calculating a cross price elasticity of demand. Despite the lack of explicit prices, the *implicit* price of public schooling may be inferred from the housing market using the hedonic approach, and the implicit price may be used to estimate a demand curve (Rosen, 1974). Rosen (p. 40) points out that his implicit market framework is particularly well-suited to the analysis of local public goods like schooling, and many studies have used Rosen's technique to find the capitalization of and demand for non-market goods like environmental quality (Brasington and Hite, 2005; Beron, Murdoch and Thayer, 2001; Zabel and Kiel, 2000) and schooling services (Brasington, 2002; Reiter and Weichenrieder, 1997; Jud and Watts, 1981).

The first stage in Rosen's two-stage demand technique is to regress house price as a function of the attributes of housing, to find the marginal attribute prices. But there is an identification problem between the first-stage hedonic and the second-stage demand regressions (Tinbergen, 1956; Brown and H. Rosen, 1982). Although there are single-equation methods to address identification (e.g., Quigley, 1982; Ekeland, et al., 2002), Brown and Rosen's (1982) market segmentation approach is the most widely accepted solution in the literature. According to Ekeland, Heckman and Nesheim (2002, p. 307), "If preferences are stable and the distributions of preferences across markets are stable, but technologies are different for exogenous reasons, then multimarket variation [Brown and Rosen's approach] shifts the hedonic function against stable preferences and identifies preference parameters."

This study therefore derives marginal prices following Brown and Rosen's suggested method of segmenting the sample by housing market to deal with the identification problem. A separate hedonic house price function is estimated for each of the seven major urban areas in Ohio. Estimating each urban area separately results in seven schooling coefficients.

3.2 Rosen's (1974) Second Stage Demand Estimation

The seven coefficients from the first-stage house price hedonics are used to calculate the implicit price of public school quality, which is the partial derivative of house price with respect to public school quality in each hedonic. The implicit prices are then pooled and a single demand equation is estimated to achieve identification. All previous segmentation studies use urban areas to segment their housing markets, and they commonly use four to seven urban areas (e.g., Palmquist, 1984; Brasington, 2003; Zabel and Kiel, 2000). Armed with a price of public schooling, the demand for public schooling may be estimated, yielding the cross price elasticity between public schooling and the price of private schooling.

4. Econometric Issues

4.1 The First Stage House Price Hedonics

Consider the traditional least squares hedonic estimation given by Equation (1), where v is house value and X is the matrix of explanatory variables:

$$v = X\beta + \varepsilon, \quad \varepsilon \sim N(0,\sigma^2) \tag{1}$$

House price hedonic regressions with individual sale prices such as Equation (1) tend not to be statistically independent. In fact, tests for statistical independence often show spatial autocorrelation in the residuals. Spatial autocorrelation is expected for at least three reasons. One, nearby houses have similar prices. Two, neighbors' behavior can affect a house's value directly or through subdivision associations. And three, non-housing determinants of house value are not fully captured by the variables included in the hedonic regressions (LeSage, 1997). Estimating Equation (1) with ordinary least squares does not account for spatial dependence between observations, which may lead to biased, inefficient and inconsistent parameter estimates (Anselin, 1988, p. 58-59).

The general spatial model addresses the problem of spatial dependence. The general spatial model includes a spatial lag of the dependent variable as well as a spatial lag of the residual as in Equation (2):

$$v = \rho W_1 v + X\beta + \mu \tag{2}$$

$$\mu = \lambda W_2\, \mu + \varepsilon, \quad \varepsilon \sim N(0,\sigma^2 I_n)$$

In Equation (2) the scalar term ρ is the spatial autoregressive parameter to be estimated. It measures the degree of spatial dependence between the values of nearby houses in the sample. The W terms are n by n spatial weight matrices. They have non-zero entries in the i,jth position, reflecting houses that are nearest neighbors to each of the i homes in the sample. The current study uses Delauney triangularization (Pace,

2003) to construct the spatial weight matrices W_1 and W_2. The Delauney triangularization technique uses a contiguity algorithm to select the optimal number of neighbors to allow for each house and assigns the weight each neighboring house is given. For example, house number 1052 might be assigned four neighbors with weights 0.10, 0.30, 0.25, and 0.35, while house number 15,382 might be assigned six neighbors with weights 0.50, 0.15, 0.15, 0.05, 0.05 and 0.10.[2] In this manner the spatial weight matrix W summarizes the spatial configuration of the houses in the sample. Next, μ is the vector of residuals, which also exhibits spatial dependence. The degree of spatial dependence in the residuals is estimated by the parameter λ, while ε is a white noise error term. Equation (2) uses the same weight matrix to represent both W_1 and W_2. Previous research (Anselin, 1988) claims ρ and λ are not identified when the same W is used, but Kelejian and Prucha (2004) prove they are.

The model in Equation (2) uses maximum likelihood, which may help with identification of the demand curve beyond the traditional method of market segmentation (Epple, 1987). The log-likelihood for the model in Equation (2) takes the following form (LeSage, 1998, p.61):

$$ln\ L = C - (n/2)\ ln\ (\sigma^2) + ln(|A|) + ln\ (|B|)\ - (\sigma^2/2) ln(e'B'Be) \tag{3}$$

where

$$e = (Av - X\beta) \tag{4}$$

$$A = (I_n - \rho W_1)$$

$$B = (I_n - \rho W_2)$$

and C is a constant term that does not involve the parameters.

The need to compute the log-determinant of the n by n matrix (I_n - ρW) makes it computationally difficult to solve the maximum likelihood problem in Equations (3) and (4). Operation counts for computing the determinant grow with the cube of n for dense matrices. However, W is sparse: most of its elements are zeroes. The sparsity of W may be exploited (Pace, 1997; Pace and Barry, 1997a, 1997b) so that a personal computer can handle the large data set estimations with relative ease. The Cholesky decomposition is used to estimate the log-determinant $|I_n - \rho W|$ over a grid of values for ρ restricted to the interval [0,1]. This log determinant uses the Monte Carlo estimator set forth by Barry and Pace (1999), which allows larger problems to be tackled without the memory requirements or sensitivity to orderings associated with the direct sparse matrix approach.

Spatial statistics greatly improves cross-sectional regression estimates that are spatial in nature. Part of the improvement stems from incorporating the influence of omitted variables (Anselin, 1988, p.103; Pace, Barry and Sirmans, 1998). Traditional hedonic estimation does not address omitted variable bias. Attempts to circumvent the problem include focusing on narrow geographic areas where many influences are already controlled for, or including vast numbers of explanatory variables to capture every influence which diligent data collection can offer. The benefits of spatial statistics over alternative approaches are discussed in Brasington and Haurin (2006). An intuitive explanation of how spatial statistics helps capture the influence of omitted variable bias is included in Brasington and Hite (2005), while a mathematical proof is available in Griffith (1988, p. 94-107).

4.2 The Second Stage Demand Regression

The same spatial dependence and omitted variable problem that affects the first stage house price hedonic regressions also affects the second stage demand regression. While the general spatial model was determined to be the most appropriate model for the first stage hedonic regressions, the spatial error model is the most appropriate model for the second stage demand regressions.[3] The spatial error model is the same as Equation (2) but with ρ = 0. The log-likelihood for this model may be found in Brasington and Sarama (2005) and LeSage (1999, p.76).

The second-stage demand regression must also correct for the endogeneity of the quantity of public schooling. Actually, instrumentation may not be necessary when spatial statistics is used (Brasington and Hite, 2005). Endogeneity is a problem of omitted factors being correlated with the regressors. Spatial statistics helps control for the influence of omitted variables, thus alleviating the need to treat regressors endogenously. But there is no harm done to the spatial estimation technique by instrumenting (Anselin, 1988). Therefore the price of public schooling is instrumented in the demand regression. Another potential problem in the estimation of the demand curve is Tiebout bias (Goldstein and Pauly, 1981). Rubinfeld, et al. (1987) inspire the inclusion of the community growth rate to help mitigate Tiebout bias, which helps capture people moving in recently.

5. Data

5.1 Choice of First Stage House Price Hedonic Variables

The house price hedonic regressions in Equation (2) are based on a data set of 93,134 houses that sold in the year 2000 in the state of Ohio. The house transactions are spread throughout the seven major urban areas in Ohio: Akron, Cincinnati, Cleveland, Columbus, Dayton, Toledo, and Youngstown, and the average sale price is $135,543. The house characteristics used are an air conditioning dummy, the number of fireplaces, the number of full and partial bathrooms, square feet of lot, age of the house, and the size of the house. The squares of lot size, house size, and age are included because these variables may influence a house's value in a nonlinear fashion.

Many community attributes may affect house price. One may rely on the spatial statistical technique to capture the influence of the community attributes, like Dubin (1998), but there is no harm in specifically controlling for neighborhood attributes (Brasington and Haurin, 2006). We include the tax rate, air pollution, neighborhood racial heterogeneity, and neighborhood income levels as controls. To control for the attractiveness of private schools, we include math proficiency test passage rates for the nearest private school to each house. But the focus variable, the variable from which Rosen's implicit price must be calculated, is the quality of schooling in each house's assigned public school district.

[Insert Table 1 about here]

Public schooling is one of the most important determinants of house price. Recent house price hedonic studies have measured school quality by per-pupil expenditures, proficiency test scores, and value added measures. Brasington and Haurin (2006) reject the use of value added measures. They find proficiency test scores are the most consistently valued measure of school quality, with expenditures a reasonable substitute when proficiency tests are unavailable. In fact, the Brasington and Haurin regressions, which are based on the same data as in the current study, report that representative value added measures have the anticipated relation with house price in only 11 out of 48 regressions. Although expenditures will be tried also, the main school performance variable adopted is the passage rate on the Ohio 9th-grade proficiency test. The sections are reading, writing, math, science, and citizenship.[4]

Because seven house price hedonic regressions are performed, Table 2 shows variable means for each of the seven urban areas.

[Insert Table 2 about here]

5.2 Choice of Second Stage Demand Variables

The implicit price of a unit of public schooling is created from the first stage house price hedonic regressions and used as the dependent variable in a demand for public school quality regression. The quantity of public schooling is measured by proficiency passage (Brasington, 2002; Duncombe and Yinger, 2000; Jud and Watts, 1981). To estimate the cross price elasticity public and private schooling, private school tuition is chosen as the price of private schooling.[5]

There are reasons aside from quality and price that determine whether a household uses private or public schools. Houses are assigned to nearby public schools, but the nearest private school may be far away, making private school attendance unattractive or impractical. For this reason the distance from each house to the nearest private school is included as a control variable in the demand regression. In addition, most private schools in Ohio are Catholic religious schools. To control for the desire for religious instruction, the percent of Catholics in the region is included.

The growth rate of the community is included to help control for Tiebout bias, as described in the Econometric Issues section. Other variables are included as potential shifters of the demand for public schooling. These include income levels, education levels, and the percentage of houses that are owner-occupied, as opposed to renter-occupied. Table 3 shows the definitions, sources, and means of the variables used in the demand regression.

[Insert Table 3 about here]

6. Estimation Results

6.1 First Stage House Price Hedonic Regression Results

The results of the seven house price hedonic regressions are shown in Table 4.

[Insert Table 4 about here]

The spatial hedonic regressions in Table 4 explain a large percentage of the variation in house price; adjusted R-squared ranges from 0.75 to 0.81. The estimated spatial lag of the dependent variable ρ ranges from -0.002 to 0.23, and four of the ρ estimates are statistically significant. This suggests mild spatial autoregressive effects. On the other hand, the spatial error lag is always statistically significant, and the average magnitude is 0.38, suggesting moderate error dependence. The parameter estimates of the house characteristics generally have the expected sign.

The focus variables are the measures of public and private school quality. Private school proficiency test passage is positively related to house prices in four of seven regressions. There are no studies in the literature with which to compare elasticities, as far as the author is aware. Public school proficiency is positively related to house price in six of the seven hedonic regressions. Because the dependent variable and the public proficiency variable are measured in natural logs, the parameter estimates are elasticities.[6] Among the six significant estimates, Toledo has the lowest elasticity of house price with respect to proficiency test scores: 0.07; Akron has the largest: 0.29.[7] The parameter estimates differ because there are different supply and demand conditions for schooling in each urban area. The availability of housing in school districts of different quality is not uniform, and there is a different supply of public and private schools in each urban area, which contributes to the different parameter estimates.[8] Having variation in the parameter estimates helps achieve identification in the manner Palmquist (1984), Epple (1987), Brown and Rosen (1982), Zabel and Kiel (2000), and Brasington (2003) suggest. The average elasticity of house prices with respect to public proficiency passage is 0.15, which compares to 0.21 in Brasington (2002), 0.54 in Hayes and Taylor (1996), 0.20 in Hite, et al. (2001), 0.76 in Clapp, Nanda and Ross (2005), 0.19 in Jud and Watts (1981), 1.10 in Downes and Zabel (2002), and 0.27 in Figlio and Lucas (2004).[9]

6.2 Second Stage Demand Regression Results

The results of the demand for public education regressions begin in Table 5.

[Insert Table 5 about here]

Second-stage hedonic demand estimations traditionally use least squares and limited information maximum likelihood (LIML). Demand is first estimated using these traditional approaches so the impact of using spatial statistics in the Delauney SEM column may be assessed.[10] The Delauney SEM column is a spatial error model where the weight matrix is formed by Delauney triangularization. The adjusted R-squared jumps from 0.13 in the non-spatial models to 0.66 in the Delauney SEM model, and the spatial error parameter is 0.81, which is large and highly statistically significant, suggesting that ignoring spatial dependence could markedly alter estimation results.

The OLS and LIML columns of Table 5 show a weaker parameter estimate for the quantity of public schooling than the Delauney SEM model. Most demand studies report a price elasticity of demand ranging from -0.20 to -0.40 (Reiter and Weichenrieder, 1997), and a non-spatial demand study using a similar Ohio data set reports an elasticity of -0.11 (Brasington, 2002). But the price variables in the current study are calculated from house price hedonics and demand regressions that address spatial dependence. The

Delauney SEM price elasticity of demand of -1.72 suggests that ignoring spatial dependence biases the price elasticity of demand upward.[11]

DISTANCE TO PRIVATE SCHOOL is significantly related to the demand for public schooling in all models, but the magnitude of the elasticity drops from 0.20 in the OLS model to a trivial 0.08 in the Delauney SEM model. All else constant, having a larger percentage of Catholics is positively related to the demand for public schooling, although the elasticity drops from 1.72 in the OLS model to 0.74 in the Delauney SEM model. The income elasticity of demand is a trivial 0.07 in the OLS model but rises to 0.31 in the Delauney SEM model. The 0.31 estimate is slightly stronger than that found by Rubinfeld, Shapiro and Roberts (1982), slightly weaker than the 0.38 to 0.83 range found by Bergstrom and Goodman (1982), weaker than the 0.87 found by Duncombe and Yinger (2000), and nearly identical to the 0.32 estimate found by Brasington (2002) using 1991 Ohio data in non-spatial regressions. Going from non-spatial to spatial models makes OWNER OCCUPIED and %LESS B.A. flip signs.

The focus variable is TUITION, from which the cross price elasticity between the quantity of public schooling and the price of private schooling is calculated. The OLS and LIML models show cross price elasticities of 0.65 and 0.60, while the Delauney SEM elasticity is 0.32. Allen and Shen (1999) find the cross price elasticity between private college enrollments and public university tuition is –0.02. One may debate how comparable the elasticities are between the different levels of schooling, but the literature provides little comparison for the 0.32 elasticity.

The 0.32 cross price elasticity must be carefully interpreted, both in what it says and what it cannot say. It is positive, which says private schooling is a substitute for public schooling. The literal interpretation is that, at the mean, a one percent decrease in the price of private schooling would be associated with a 0.32 percent fall in the demand for public schooling. But average private school tuition in Ohio is $6600, so a one percent fall in the price of private schooling would amount to less than a $100 voucher. All partial voucher proposals are more generous than this. Suppose President Bush's $1500 voucher bill had passed in 2001.

Suppose average private school tuition were $6600 and parents could supplement the voucher with additional money. It is also important to consider public school taxes. Average expenditures per public school student in Ohio is currently $7982. But because not every adult (or corporation) has children, and the amount everyone pays toward public schools varies by person, it is difficult to estimate how much the typical person pays for public schools. For a rough approximation, through property and income and sales taxes, suppose the typical parent pays $3000 for public schools, which gets paid whether the parent uses public school or not. In these circumstances a $1500 voucher would reduce the price of attending private schools from ($3000 + $6600 =) $9600 to ($3000 + $6600 - $1500) = $8100, reducing the price of private schooling by about 16%. The 0.32 elasticity implies that the $1500 voucher would reduce the demand for public schooling by (0.16 * 0.32 =) 5.1%.

The mechanisms behind the 5.1% reduced demand could take many forms, but the end result is a 5.1% lower amount of public schooling demanded. Exactly what combination of student transfers from public schools, reduced public school expenditures, and cream-skimming cause the 5.1% decline cannot be specified, but flight from public schools, reduced expenditures, and cream-skimming are inter-related. As the brightest students flee the public schools (Epple and Romano, 1998), the lower peer effects depress public school outcomes. As students take their voucher money to private schools, public school budgets are cut, perhaps leading to larger class sizes and lower schooling outcomes. And as the constituent base of the public schools erodes, tax levies are more difficult to pass, also reducing school budgets. The numerical example of a $1500 voucher possibly leading to a 5.1% drop gives the impression that, at least in the short run, a voucher system would not cause people to demand much less public schooling, and something less than a mass exodus of parents would switch from public to private schools. But there are other effects of vouchers, which are touched upon in the conclusion.

The Delauney triangularization chooses the number of neighbors, but for theoretical reasons it may be desirable to include a large enough number of neighboring houses so that some of the houses are probably in neighboring school districts, to account more directly for spillovers between school districts. For this reason two extensions are shown in Table 5. The first extension selects the nearest 200 neighbors to each house and re-estimates the spatial error model. The results are shown in the 200-Neighbor SEM column. The second extension recognizes that if a house is in the middle of a school district, even selecting the nearest 200 houses may not yield any houses outside our own school district. The second extension uses a unique algorithm consisting of two separate weight matrices. One weight matrix consists of the ten nearest neighbors from within our own school district, and the other weight matrix consists of the ten nearest neighbors from outside our own school district. Many combinations were tried, but the results shown assign a 90% weight to the within-school district weight matrix and a 10% weight to the outside-school district weight matrix.[12] Most elasticities change little, but the cross price elasticity goes from 0.32 in the Delauney SEM to 0.49 in the 200-Neighbor SEM. At the same time the optimal log-likelihood falls from -587,572.1 in the Delauney SEM to -597,429.1 in the 200-Neighbor SEM to -1,014,737.1 in the 10 In 10 Out SEM. The results suggest that the Delauney weight matrix is the most appropriate of the three. In fact, additional 10 In 10 Out SEM models yield even worse fit when additional weight is given to the outside-school district weight matrix.

6.3 Second Stage Demand Regression Results: Expenditures and House Size Extensions

An alternative to proficiency test scores to measure school quality is per pupil expenditures. Table 6 begins with the results of three demand regressions that use LN EXPENDITURES in the house price hedonic regressions in place of LN PUBLIC PROFICIENCY, and they use the price and quantity counterparts PRICE PUBLIC XP and QUANTITY PUBLIC XP in the second-stage demand regressions.

[Insert Table 6 about here]

The first expenditures model, OLS Expenditures, uses ordinary least squares in both stages.[13] The Expenditures Delauney SEM uses the general spatial model in the hedonic regressions and a spatial error model with a Delauney weight matrix in the demand regression.[14] The 200-Neighbor Expenditures SEM column of Table 6 uses a spatial error model with the nearest 200 neighbors for its spatial weight matrix.

When expenditures are used to estimate the demand curves, two of the three demand curves slope upward. The only demand curve that slopes downward shows a series of theoretically curious results. The most damning of these are that public and private schooling are complements and that being close to private schools makes people demand public schooling more.

Houses with a large number of bedrooms are more likely to contain children than houses with few bedrooms. If having more bedrooms makes a house more marketable to families that use public schools, houses with many bedrooms may have different price and cross price elasticities of demand for public schooling than houses with few bedrooms. The analysis is repeated splitting the sample into houses with three or fewer bedrooms, and houses with four or more bedrooms. The results of the demand curve regressions using a spatial error model with Delauney neighbors are shown in the Small House Delauney SEM and Large House Delauney SEM columns of Table 6. The own price elasticities of demand are similar for the large and small house samples, but the cross price elasticity differs: it is 0.19 for small houses and 0.36 for large houses. The data suggest that households with children are nearly twice as responsive to changes in the price of private schooling than households without children. The results appear to not to stem from a high correlation between the number of bedrooms and income.[15] Also, the income elasticity of demand for large houses (0.343) is five times that of small houses (0.067), again suggesting that households with children care more about public school quality than households with no children.

Proponents of vouchers argue that vouchers would benefit students in low-income districts most; opponents say that low-income school districts are the most likely to suffer from funding cuts as students flee to private schools. To investigate, an unreported spatial error demand model with a Delauney weight matrix is run that includes an interaction term.[16] The cross price elasticity is calculated for the 25th and 75th percentiles of income. Poor homeowners have a cross price elasticity of 0.30; it is 0.34 for the rich. It seems that the rich and the poor have the same view on the substitutability of public and private schools. The actual flight to private schools, and subsequent financial difficulties and incentives for improvement for public schools, will depend on the exact formulation of school choice program, but it will apparently not hinge on differing attitudes of the rich and the poor toward private schools.

7. Conclusions

Will school choice provide competition for public schools? The answer depends largely on the degree to which public and private schooling are substitutes. The current study estimates the demand for public schooling and finds the cross price elasticity between public schooling and the price of private schooling is 0.32. Public and private schooling seem to be moderately weak substitutes. That they are moderately weak substitutes suggests that a voucher system or a tuition tax credit that makes private schools more affordable will not cause a mass exodus from public schools, at least not immediately. The results of the current study must be cast in light of previous research on the demand for private schooling and the experiences of other nations with voucher systems.

There seem to be no other demand for K-12 public schooling studies that calculate the cross price elasticity of private schooling. However, there are studies that estimate the demand for private schooling. Some studies find the demand for private schooling is sensitive to changes in private school tuition (Sandy, 1992; West and Palsson, 1988), some find the demand for private schooling is not sensitive to changes in private school tuition (Buddin, Cordes and Kirby, 1998; Chiswick and Koutromanes, 1996), and others find mixed results depending on whether primary or secondary schools are examined (Sandy, 1992; Hoenack, 1992). The evidence is mixed on whether private school usage is responsive to changes in tuition, providing no clear evidence whether parents would switch from public to private schools if a voucher system or tuition tax credits made private schools cheaper.[17] Another way to see whether parents would switch to private schools is to see what happened in other countries that have enacted voucher plans.

The United States is not the only country to experiment with school vouchers. Bangladesh, Belize, Chile, Colombia, Czech Republic, Guatemala, Ivory Coast, Lesotho, Poland, Sweden, and the United Kingdom have voucher systems where the vouchers may be used toward the public or private school of the parents' choice. British Columbia, Quebec, Manitoba, Saskatchewan, Alberta, Japan, the Netherlands, Belgium, France, and New Zealand also have state support for private schools.[18] While Sandy (1992) finds Americans with low socio-economic status support vouchers the most, Willms and Echols (1992) find that Scottish parents with high socio-economic status were the ones who took advantage of Britain's school voucher system. Did the introduction of vouchers in other nations cause a mass exodus from the public schools? The proportion of students attending private schools more than doubled eight years after Chile adopted private school vouchers. On the other hand, just 17% of voucher recipients in Puerto Rico switched from public to private schools; most Puerto Rican voucher recipients transferred from one public school to another (West, 1997). Belgium now has one of the highest private school attendance rates in the world, but New Zealand's private school attendance rate has hardly changed since the government began subsidizing private schools in 1974 (Toma, 1996).

If the experiences of other nations were similar, perhaps conclusions could be drawn about the likely effect of school vouchers and private school tuition tax credits in the United States. But they are not. The response of each nation may depend on how easily each nation's residents believe private schools may be substituted for public schools. The current study's cross price elasticity of 0.32 suggests that public and private schooling are not powerful substitutes in the United States. It is dangerous to interpret regression results beyond small, marginal changes in the explanatory variables. But given the lack of guidance from previous literature, and the importance of the public policy question, any information we can get on the possible effects of a generous voucher program may be worth the risk of stretching the 0.32 cross price elasticity beyond its limits. This said, a voucher program as generous as Colombia's that covers half the cost of private schooling may decrease the demand for public schooling in the U.S. by 16%.

Some opponents of school vouchers in the United States argue that vouchers would cause Americans to flock to private schools en masse, leaving the poor in gutted, underfunded, and decaying public schools (e.g., Krashinsky, 1986; Ansell, 2003). The cross price elasticities of the current study do not support such a scenario. If the 16% number means that 16% of public school students would switch to private schools—which is one of many possible interpretations of the 16% number—public schools would still retain their dominant market share. Furthermore, most private school systems are already near full capacity, so not all 16% of public school users could switch to private schools. Faced with excess demand, private schools may raise tuition rates to exclude almost all additional customers, stemming the 'mass exodus' from public schools until more private schools can be built.

The results of the current study must also account for the lack of variety seen in private schools today. Existing voucher experiments in the United States are small programs with strictly limited participation (Merrifield, 2002; Merrifield and Salisbury, 2005). Such experiments provide little clue about how many students would switch if there were widespread voucher programs. The current study is based on the premise that public schools already face a certain degree of competition from existing private schools. By studying the elasticity of substitution between them, it can provide some clue about how many students would take advantage of private school vouchers and tuition tax credits. But the 0.32 elasticity of substitution generated by today's data may underestimate the long-run response to vouchers. Today, parents must choose between "free" public schools and a limited set of private school alternatives. But as Merrifield (2002; and Salisbury, 2005) notes, a voucher system may spawn a supply-side response that yields a vast array of private schools with innovative, attractive educational menus. As the alternatives become more attractive, a larger proportion of parents will probably redeem their vouchers at private schools, so the cross price elasticity of the current study may best be viewed a lower-bound, short-run estimate of the degree to which public schools might lose support to private schools under a voucher program.

In short, given the 0.32 cross price elasticity, capacity constraints, and the lack of variety of types of private schools, the current study suggests that if vouchers or tuition tax credits were enacted, public schools would have some time to compete to retain their students. Even though the move from public to private schools would at first resemble a trickle rather than a steady stream, the public schools may still respond to the increased competition. The mere introduction of school choice may scare public schools into greater efficiency and effectiveness (Figlio and Rouse, 2006), encouraging parents to continue to support the public schools with their tax levies, school voucher money, and talented children; and limiting the market share of private schools to something close to the 12% it currently commands.

The study supports the following additional findings. The average elasticity of house price with respect to public proficiency test scores is 0.15. Own price elasticity of demand is -1.72. The spatial model reveals a more price elastic demand curve than studies that fail to address spatial dependence and omitted variable bias through spatial statistics. Income elasticity of demand is 0.31, and poor and rich households have nearly identical views on the substitutability between public and private schools. Compared to those living in houses with three or fewer bedrooms, people who live in houses with a large number of bedrooms have stronger cross price and income elasticities of demand for public schooling.

TABLE 1: Hedonic Definitions, Sources, and Means[a]

Variable Name	Definition (Source)	Full Sample Means (σ)
HOUSE PRICE	Sale price of house in 2000 in U.S. dollars (1)	135543 (100225)
ONESTORY	Dummy variable = 1 if house is one story (1)	0.44 (0.50)
AIR CONDITIONING	Dummy variable = 1 if house has central air conditioning (1)	0.30 (0.46)
FIREPLACES	Number of fireplaces the house has (1)	0.49 (0.59)
FULLBATHS	Number of full bathrooms (toilet plus shower) the house has (1)	1.46 (0.60)
PARTBATHS	Number of partial bathrooms (toilet but no shower) the house has (1)	0.46 (0.54)
AGE	Age of house in hundreds of years (1)	0.42 (0.31)
HOUSE SIZE	Building size in tens of thousands of square feet (1)	0.16 (0.07)
YARD SIZE	Lot size in tens of thousands of square feet (1)	2.03 (5.13)
TAX RATE	Tax year 2000 class 1 (agricultural and residential) tax rate in school district in effective mills (2)	32.50 (6.12)
AIR POLLUTION	All point-source air releases in Census tract of the house in tens of thousands of pounds (3)	2.28 (24.24)
RACIAL HETEROGENEITY	Leik (1966) index of racial heterogeneity of Census block group of the house, where 0 is racially homogeneous, 1 is racially heterogeneous (4)	0.10 (0.10)
INCOME	Median income of households in Census block group in tens of thousands of U.S. dollars (4)	5.26 (2.14)
PRIVATE PROFICIENCY	Percent of private school students proficient or above in math section for grade 9 test for sum (average) of 2000 and 2001 test years, for the nearest private school to each house (5)	49.42 (23.92)
PUBLIC PROFICIENCY	Percent of 9th grade students in public school district who passed all five sections (citizenship, reading, writing, math, science) of the Ohio proficiency test in 2000 test year (6)	63.81 (19.70)
EXPENDITURES	Total expenditure per pupil in public school district in thousands of U.S. dollars, for 2000-2001 school year (6)	7.98 (1.21)
Sources: (1) First American Real Estate Solutions (2002); (2) Ohio Department of Taxation (2003); (3) U.S. Environmental Protection Agency (2002); (4) GeoLytics CensusCD 2000 (2002); (5) Data collected by Sheila Milligan of Ohio Department of Education (2005) (6) Ohio Department of Education (2002)		

[a]Number of observations = 93,134. Full sample means shown with standard deviation in parentheses.

TABLE 2: Hedonic Means by Urban Area[a]

Variable	Akron	Cincinnati	Cleveland	Columbus	Dayton	Toledo	Youngstown
HOUSE PRICE	131209	143271	139824	151690	111232	114059	90038
	(92186)	(106264)	(98688)	(117188)	(68236)	(76495)	(53296)
ONESTORY	0.51	0.48	0.34	0.39	0.65	0.48	0.53
	(0.50)	(0.50)	(0.47)	(0.49)	(0.48)	(0.50)	(0.50)
AIR CONDITIONING	0.065	0.15	0.23	0.59	0.54	0.08	0.10
	(0.25)	(0.36)	(0.42)	(0.49)	(0.50)	(0.27)	(0.30)
FIREPLACES	0.49	0.55	0.48	0.54	0.46	0.34	0.46
	(0.63)	(0.58)	(0.62)	(0.58)	(0.56)	(0.53)	(0.57)
FULLBATHS	1.42	1.54	1.35	1.61	1.47	1.30	1.25
	(0.60)	(0.61)	(0.58)	(0.60)	(0.59)	(0.52)	(0.48)
PARTBATHS	0.45	0.46	0.44	0.56	0.34	0.38	0.37
	(0.54)	(0.54)	(0.54)	(0.53)	(0.51)	(0.52)	(0.52)
AGE	0.44	0.40	0.49	0.32	0.46	0.52	0.49
	(0.29)	(0.30)	(0.29)	(0.32)	(0.29)	(0.31)	(0.24)
HOUSE SIZE	0.16	0.17	0.16	0.17	0.16	0.15	0.15
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.06)	(0.06)
YARD SIZE	2.02	2.16	2.03	1.96	1.97	1.68	2.49
	(4.22)	(6.07)	(5.03)	(5.14)	(5.04)	(3.75)	(4.80)
TAX RATE	30.02	31.92	33.81	33.62	31.42	31.00	31.96
	(3.76)	(5.36)	(8.06)	(5.99)	(4.56)	(4.10)	(4.31)
AIR POLLUTION	1.29	4.34	0.69	2.69	0.98	2.97	2.93
	(7.48)	(48.68)	(7.39)	(15.31)	(7.53)	(11.61)	(14.55)
RACIAL HETEROGENEITY	0.077	0.083	0.119	0.114	0.085	0.133	0.075
	(0.069)	(0.073)	(0.138)	(0.085)	(0.066)	(0.107)	(0.080)
INCOME	5.09	5.51	5.19	5.71	4.85	4.81	4.16
	(2.17)	(2.20)	(2.07)	(2.37)	(1.75)	(1.81)	(1.28)
PRIVATE PROFICIENCY	51.45	69.57	42.45	36.67	67.81	43.02	27.96
	(22.30)	(19.69)	(17.81)	(20.30)	(22.07)	(19.66)	(5.94)
PUBLIC PROFICIENCY	63.62	64.32	62.23	65.70	62.89	61.97	65.75
	(17.76)	(17.91)	(21.23)	(18.30)	(22.14)	(20.52)	(21.33)
EXPENDITURES	7.85	7.62	8.68	7.96	7.57	7.87	7.31
	(0.71)	(1.29)	(1.40)	(1.00)	(1.13)	(0.54)	(0.82)
No. of observations	8446	19098	22670	22251	9381	7260	4028

[a]Means shown with standard deviation in parentheses below.

TABLE 3: Demand Variable Definitions, Sources, and Means[a]

Variable Name	Definition (Source)	Full Sample Means (σ)
PRICE PUBLIC	Implicit price of a unit of public schooling for each house in U.S. dollars, based on PUBLIC PROFICIENCY in hedonic regressions (1)	280.18 (296.15)
PRICE PUBLIC XP	Implicit price of a unit of public schooling for each house in U.S. dollars, based on EXPENDITURES in hedonic regressions (1)	1.58 (4.58)
TUITION	Tuition of the nearest private school to each house in U.S. dollars (2)	6599.49 (3964.32)
QUANTITY PUBLIC	Quantity of public schooling; percent of 9th grade students in public school district who passed all five sections (citizenship, reading, writing, math, science) of the Ohio proficiency test in 2000 test year (6)	63.81 (17.21)
QUANTITY PUBLIC XP	Quantity of public schooling; total expenditure per pupil in public school district in millions of U.S. dollars, for 2000-2001 school year (6)	0.0080 (0.0009)
DISTANCE TO PRIVATE	Distance from each house to the nearest private school in miles (3)	4.18 (3.82)
CATHOLIC	Percent of the total population of each county the house is in that is Catholic in 1990 (4)	21.27 (11.04)
INCOME	Median income of households in Census block group in tens of thousands of U.S. dollars (5)	5.26 (2.14)
GROWTH RATE	Population growth; percent change in kindergarten thru grade 12 enrollment minus unauthorized attendance minus out of state enrollment plus non-attending pupils between 1997-1998 and 2000-2001 school years (6)	-2.52 (9.00)
%NO HIGH SCHOOL	Percent of persons 25 years or older in Census block group whose highest educational attainment is less than a high school degree or equivalent (5)	13.88 (10.04)
%HIGH SCHOOL	Percent of persons 25 years or older in Census block group whose highest educational attainment is a high school diploma, including equivalency (5)	31.36 (12.01)
%LESS B.A.	Percent of persons 25 years or older in Census block group whose highest educational attainment is more than a high school diploma, but less than a bachelor's degree, including Associate degree and some college with no degree (5)	27.45 (6.46)
OWNER OCCUPIED	Percent of occupied housing units in Census block group that are occupied by owners rather than renters (5)	76.28 (19.37)
Sources: (1) Derived from first stage house price hedonic regressions; (2) Phone survey of all Ohio private schools that contain 9th grade; (3) Calculated from Street Map 3.0, geocode.com, and Arc View softwares; (4) Bradley, et al. (1992); (5) GeoLytics CensusCD 2000 (2002); (6) Ohio Department of Education (2002)		

[a]Number of observations = 93,134. Means shown with standard deviation in parentheses.

TABLE 4: First Stage House Price Hedonic Regressions from General Spatial Model of Equation (2)[a]
Dependent variable is LN HOUSE PRICE

	Akron	Cincin-nati	Cleveland	Columbus	Dayton	Toledo	Youngs-town
CONSTANT	9.65	10.51	9.24	10.16	9.46	8.27	8.35
	(929.04)	(6304.21)	(10160.71)	(9211.67)	(1766.01)	(291.76)	(370.52)
ONESTORY	0.018	0.036	-0.002	0.025	0.003	-0.019	0.049
	(2.16)	(6.56)	(-0.34)	(5.48)	(0.37)	(-2.60)	(4.27)
AIR CONDITIONING	-0.216	-0.019	0.015	0.053	0.064	-0.007	0.070
	(-12.76)	(-2.14)	(2.94)	(10.60)	(10.82)	(-0.48)	(4.95)
FIREPLACES	0.064	0.079	0.047	0.056	0.062	0.074	0.078
	(10.02)	(17.62)	(12.67)	(15.81)	(11.00)	(11.16)	(9.23)
FULLBATHS	0.103	0.058	0.065	0.088	0.076	0.084	0.074
	(12.27)	(11.44)	(13.36)	(19.57)	(11.35)	(9.89)	(6.46)
PARTBATHS	0.070	0.051	0.065	0.050	0.046	0.058	0.063
	(9.15)	(10.79)	(15.61)	(11.70)	(7.57)	(7.97)	(6.86)
AGE	-0.75	-0.46	-0.21	-0.51	-0.51	-0.43	-1.04
	(-19.69)	(-15.29)	(-8.12)	(-21.54)	(-12.91)	(-9.90)	(-16.96)
AGE SQUARED	0.33	0.13	0.01	0.25	0.20	0.08	0.48
	(9.88)	(5.28)	(0.60)	(13.71)	(7.44)	(2.38)	(10.06)
HOUSE SIZE	3.20	3.96	2.97	4.25	3.39	3.33	3.21
	(21.89)	(35.20)	(54.99)	(45.78)	(22.25)	(19.62)	(11.44)
HOUSE SIZE SQUARED	-1.91	-2.21	-0.78	-2.91	-1.89	-1.49	-1.57
	(-8.96)	(-11.54)	(-28.52)	(-19.78)	(-7.17)	(-4.87)	(-2.68)
YARD SIZE	0.011	0.013	0.008	0.012	0.018	0.015	0.016
	(6.42)	(47.53)	(32.01)	(43.05)	(11.10)	(9.02)	(7.91)
YARD SIZE SQUARED	-5.9E-05	-3.5E-05	-2.3E-05	-4.6E-05	-0.00018	-0.00015	-0.00022
	(-1.76)	(-22.18)	(-10.11)	(-10.14)	(-6.10)	(-3.81)	(-4.32)
TAX RATE	-0.0015	0.0042	0.0013	0.0073	0.0038	-0.0048	0.0013
	(-1.13)	(6.20)	(3.82)	(10.41)	(3.08)	(-4.96)	(0.96)
AIR POLLUTION	6.6E-05	8.0E-06	3.1E-04	-5.1E-05	-0.0008	-7.6E-04	-0.0002
	(0.11)	(0.12)	(1.15)	(-0.25)	(-1.68)	(-2.37)	(-0.62)
RACIAL HETEROGENEITY	-0.31	-0.04	-0.19	-0.24	-0.15	-0.53	-0.45
	(-4.72)	(-0.90)	(-9.61)	(-6.75)	(-2.61)	(-13.63)	(-7.21)
INCOME	0.053	0.044	0.035	0.044	0.036	0.025	0.031
	(18.41)	(24.08)	(22.81)	(25.67)	(13.78)	(9.49)	(6.64)
PRIVATE PROFICIENCY	-0.00066	0.0025	0.001	0.00057	0.00065	-0.00037	0.00057
	(-2.82)	(12.42)	(6.10)	(3.17)	(3.41)	(-1.75)	(0.71)
LN PUBLIC PROFICIENCY	0.29	0.00037	0.21	0.09	0.21	0.07	0.15
	(17.90)	(0.04)	(26.32)	(10.76)	(11.62)	(4.78)	(8.53)
Rho (ρ)	0.013	0.001	0.074	-0.002	0.029	0.23	0.17
	(1.59)	(0.44)	(26.04)	(-0.87)	(3.04)	(26.21)	(14.12)

Lambda (λ)	0.38	0.54	0.37	0.57	0.38	0.26	0.17
	(63.80)	(409.36)	(145.46)	(207.20)	(51.27)	(36.37)	(14.66)
Adjusted R-squared	0.76	0.75	0.75	0.81	0.77	0.78	0.75
Number of obs	8446	19098	22670	22251	9381	7260	4028

[a]Parameter estimates shown with asymptotic t-ratios (Anselin, 1980) in parentheses below. Rho is the spatial autoregressive parameter from Equation (2), and lambda is the spatial error parameter from Equation (2).

TABLE 5: Second Stage Demand for Public Schooling Regressions[a]
Dependent variable is PRICE PUBLIC

	OLS	LIML	Delauney SEM	200-Neighbor SEM	10 In 10 Out SEM
CONSTANT	-39.07	47.75	346.30	302.47	419.21
	(3.32)	(4.11)	(19.08)	(19.63)	(18.81)
TUITION	0.012	0.012	0.008	0.012	0.005
	(46.06)	(46.59)	(13.16)	(32.12)	(6.53)
QUANTITY PUBLIC	-1.91	-2.07	-2.56	-2.53	-2.57
	(-23.97)	(-26.57)	(-19.98)	(-25.05)	(-16.09)
DISTANCE TO PRIVATE	5.95	6.12	3.00	3.63	0.62
	(19.66)	(20.44)	(3.80)	(8.66)	(0.47)
CATHOLIC	9.85	9.86	5.67	6.51	3.94
	(95.90)	(97.28)	(20.95)	(45.52)	(7.99)
INCOME	1.70	2.09	9.56	7.63	9.81
	(1.65)	(2.06)	(8.04)	(6.27)	(8.36)
GROWTH RATE	5.42	5.49	1.93	3.61	0.94
	(41.77)	(42.84)	(8.73)	(21.63)	(3.06)
%NO HIGH SCHOOL	-1.51	-1.59	-1.91	-2.11	-1.65
	(-9.32)	(-9.96)	(-9.87)	(-11.15)	(-8.51)
%HIGH SCHOOL	-0.54	-0.53	-1.68	-1.78	-1.53
	(-4.22)	(-4.22)	(-10.25)	(-11.68)	(-9.10)
%LESS B.A.	0.88	0.86	-1.50	-1.30	-1.77
	(4.78)	(4.74)	(-6.95)	(-5.97)	(-8.24)
OWNER OCCUPIED	0.43	0.43	-0.17	-0.03	-0.22
	(5.64)	(5.72)	(-2.13)	(-0.31)	(-2.85)
Lambda (λ)	-	-	0.81	0.61	0.91
	-	-	(325.81)	(98.29)	(290.20)
Adjusted R-squared	0.13	0.13	-	-	-
Log-likelihood	-	-	-587,572.1	-597,429.1	-1,014,737.1

[a]Parameter estimates shown with t-ratios in parentheses below; they are asymptotic t-ratios (Anselin, 1980) for the spatial models. Lambda is the spatial error parameter from Equation (2), with rho set to zero to yield the spatial error model. Number of observations = 93,134. OLS = ordinary least squares model. LIML = limited information maximum likelihood model. Delauney SEM = spatial error model with Delauney spatial weight matrix. 200-Neighbor SEM = spatial error model with nearest 200 houses for spatial weight matrix. 10 In 10 Out SEM = spatial error model with two weight matrices, one with the nearest 10 neighbors from within the same school district (assigned a 90% weight), the other with the nearest 10 neighbors from outside the same school district (assigned a 10% weight).

TABLE 6: More Second Stage Demand for Public Schooling Regressions[a]
Dependent variable is PRICE PUBLIC or PRICE PUBLIC XP

	OLS Expend-itures	Expend-itures Delauney SEM	200-Neighbor Expend-itures SEM	Small House Delauney SEM	Large House Delauney SEM
CONSTANT	-1595.09	3435.05	715.35	343.46	406.21
	(-6.80)	(11.01)	(2.46)	(19.64)	(10.37)
TUITION	-0.131	-0.023	-0.090	0.005	0.010
	(-34.62)	(-2.88)	(-16.06)	(8.59)	(9.86)
QUANTITY PUBLIC XP	166.86	-223.32	53.21	-	-
	(8.64)	(-8.07)	(2.08)	-	-
QUANTITY PUBLIC	-	-	-	-2.69	-2.91
	-	-	-	(-22.76)	(-10.59)
DISTANCE TO PRIVATE	-19.91	-61.07	-33.61	2.28	6.00
	(-4.62)	(-4.28)	(-5.02)	(3.39)	(3.13)
CATHOLIC	30.18	16.77	26.01	4.96	7.75
	(20.77)	(3.55)	(11.50)	(20.53)	(12.71)
INCOME	709.21	209.84	418.87	2.18	12.11
	(50.35)	(15.29)	(26.32)	(1.80)	(5.49)
GROWTH RATE	39.84	25.74	42.30	1.91	1.79
	(23.09)	(9.78)	(18.44)	(8.98)	(4.06)
%NO HIGH SCHOOL	36.92	-8.09	7.49	-1.78	-2.65
	(16.91)	(-3.59)	(3.00)	(-9.92)	(-6.01)
%HIGH SCHOOL	-12.96	-4.44	-14.14	-1.25	-2.54
	(-7.14)	(-2.28)	(-6.81)	(-8.18)	(-6.94)
% LESS B.A.	-8.26	-5.21	-14.10	-0.92	-2.32
	(-3.23)	(-2.09)	(-4.96)	(-4.50)	(-4.98)
OWNER OCCUPIED	-17.93	-6.34	-9.97	0.21	-0.44
	(-17.06)	(-7.04)	(-9.10)	(2.89)	(-2.52)
Lambda (λ)	-	0.90	0.74	0.79	0.79
	-	(660.13)	(537.08)	(334.06)	(200.21)
Adjusted R-squared	0.09	-	-	-	-
Log-likelihood	-	-812,850.8	-832,570.2	-444,552.3	-170,619.6
Number of obs	93134	93134	93134	68541	24593

[a]Parameter estimates shown with t-ratios in parentheses below; they are asymptotic t-ratios (Anselin, 1980) for the spatial models. Lambda is the spatial error parameter from Equation (2), with rho set to zero to yield the spatial error model. OLS Expenditures = ordinary least squares model with PRICE PUBLIC XP as dependent variable. Expenditures Delauney SEM = spatial error model with Delauney spatial weight matrix and PRICE PUBLIC XP as dependent variable. 200-Neighbor Expenditures SEM = spatial error model with

nearest 200 houses for spatial weight matrix and PRICE PUBLIC XP as dependent variable. Small House Delauney SEM is spatial error model with Delauney spatial weight matrix and PRICE PUBLIC as dependent variable with sample of houses with 3 bedrooms or less. Large House Delauney SEM is spatial error model with Delauney spatial weight matrix and PRICE PUBLIC as dependent variable with sample of houses with 4 bedrooms or more.

Acknowledgements

Thanks for data help to Ryan Bilbo, Sheila Milligan, Italia Jackson, and Paul Darby. Thanks for helpful comments from Diane Hite, Graham Crampton, Mark Andrew, Roy Lee, John Spry, Kelley Pace, Eric Hillebrand, Carter Hill, and Doug McMillin; from Peter Thompson, Richard Chisik and others at the 11/19/04 Florida International U seminar; from David Figlio, Larry Kenny, Chunrong Ai, Sarah Hamersma, Jon Hamilton and others at the 9/15/04 U Florida seminar; Christian Hilber, Lars Nesheim and others at the 6/4/04 Centre for the Economics of Education seminar; Darren Grant and John Merrifield at the 11/21/03 Southern Economic Association presentation; Meg Ledyard at the 3/18/03 Public Choice presentation; Ron Balvers, Strat Douglas and others at the 1/14/02 West Virginia U seminar; Mark Berger, Chris Bollinger, David Wildasin, Bill Hoyt and others at the 9/14/01 U Kentucky seminar; commenters at the 2/26/05 Western Regional Science presentation; and Dan Thornton and others at the 12/16/03 St. Louis Fed seminar. Thanks to Kelley Pace for programming some non-traditional weight matrices and running the more computationally intense demand regressions on his 64-GHz RAM home computer, which my 4-GHz office computer could not run until Kelley devised extra time-saving tricks. Previously titled, "School Vouchers and the Flight to Private Schools: To What Extent Are Public and Private Schools Substitutes?"

References

Allen, Robert F. and Jianshou Shen. "Some New Evidence of the Character of Competition Among Higher Education Institutions." Economics of Education Review 18(4), October 1999, p. 465-470.

Anselin, Luc. *Spatial Econometrics: Methods and Models*. London and Dodrecht: Kluwer Academic Publishing, 1988.

Anselin, Luc. 1980. *Estimation Methods for Spatial Autoregressive Structures*. Ithaca, New York: Regional Science Dissertation and Monograph Series #8.

Ansell, Susan. "Education Issues A-Z: Vouchers." Education Week web site, updated June 18, 2003. http://www.edweek.org/context/topics/issuespage.cfm?id=30.

Barry, Ronald, and R. Kelley Pace. (1999). "A Monte Carlo Estimator of the Log Determinant of Large Sparse Matrices," Linear Algebra and its Applications 289(1-3), 41-54.

Bergstrom, T. C. and R. P. Goodman. 1973. Private demands for public goods. American Economic Review 63: 280-96.

Beron, Kurt, James Murdoch and Mark Thayer. "The Benefits of Visibility Improvement: New Evidence from the Los Angeles Metropolitan Area." Journal of Real Estate Finance and Economics 22(2-3), March-May 2001, p. 319-337.

Bradley, Martin B., Norman M. Green, Jr., Dale E. Jones, Mac Lynn, and Lou McNeil. *Churches and Church Membership in the United States 1990: An Enumeration by Region, State and County Based on Data Reported for 133 Church Groupings*. Glenmary Research Center, Atlanta, GA: 1992.

Brasington, David M. "The Supply of Public School Quality." Economics of Education Review 22(4), August 2003, p. 367-377.

Brasington, David M. "The Demand for Local Public Goods: The Case of Public School Quality," Public Finance Review 30(3), May 2002, p. 163-187.
Brasington, David M. and Donald R. Haurin. "Educational Outcomes and House Values: A Test of the Value-Added Approach," Journal of Regional Science 46(2), 2006, p. 245-268.
Brasington, David M. and Diane Hite. "Demand for Environmental Quality: A Spatial Hedonic Analysis," Regional Science and Urban Economics 35(1), January 2005, p. 57-82.
Brasington, David M. and Robert F. Sarama. "House Prices, Mortgage Interest Rates, and Security of Legal Claim: An Investigation of Deed Types." Louisiana State University Department of Economics Working Paper, November 2, 2005.
Brown, James N. and Harvey S. Rosen. "On the Estimation of Structural Hedonic Price Models." Econometrica 50(3), May 1982, p. 765-768.
Buddin, Richard J., Joseph J. Cordes and Sheila Nataraj Kirby. "School Choice in California: Who Chooses Private Schools?" Journal of Urban Economics 44(1), July 1998, p. 110-134.
Chiswick, Barry R. and Stella Koutromanes. "An Econometric Analysis of the Demand for Private Schooling." Research in Labor Economics 15, 1996, p. 209-237.
Clapp, John M., Anupam Nanda, and Stephen L. Ross. 2005. "Test-Scores and Demographics: What Premiums Do They Attract in Property Values? A Panel Data Analysis," Working Paper, University of Connecticut, Department of Economics.
Dills, Angela K. 2004. "Do Parents Value Changes in Test Scores? High Stakes Testing in Texas," Contributions to Economic Analysis & Policy, 3(1), Article 10.
Downes, Thomas A. and Jeffrey E. Zabel. 2002. "The Impact of School Characteristics on House Prices: Chicago 1987-1991," Journal of Urban Economics 52: 1-25.
Dubin, Robin A. "Predicting House Prices Using Multiple Listings Data." Journal of Real Estate Finance and Economics 17(1), 1998, p. 35-59.
Duncombe, William and John Yinger. "Financing Higher Student Performance Standards: The Case of New York State." Economics of Education Review 19(4), October 2000, p. 363-386.
Ekeland, Ivar, James J. Heckman and Lars Nesheim. "Identifying Hedonic Models." American Economic Association Papers and Proceedings 92(2), May 2002, p. 304-309.
Epple, Dennis. "Hedonic Prices and Implicit Markets: Estimating Demand and Supply Functions for Differentiated Products." Journal of Political Economy 95(1), February 1987, p. 59-79.
Epple, Dennis and Richard E. Romano. "Competition Between Private and Public Schools, Vouchers, and Peer-Group Effects." American Economic Review 88(1), 1998, p. 33-62.
Epple, Dennis, David N. Figlio, and Richard E. Romano. "Competition Between Public and Private Schools: Testing Stratification and Pricing Predictions." Journal of Public Economics 88(7-8), July 2004, p. 1215-1245.
Erekson, Homer O. "Equity Targets in School Finance, Tuition Tax Credits, and the Public-Private Choice." Journal of Education Finance 7, 1982, p. 436-449.
First American Real Estate Solutions. 2002. "CRG Order #03172." Cincinnati, OH.
Figlio, David N. and Cecilia Elena Rouse. "Do Accountability and Voucher Threats Improve Low-Performing Schools?" Journal of Public Economics 90(1-2), January 2006, p. 239-255.
Figlio, David N. and Maurice E. Lucas. "What's in a Grade? School Report Cards and the Housing Market." American Economic Review 94, 2004, p. 591-604.
Gauri, Varun and Ayesha Vawda. "Voucher for Basic Education in Developing Economies: An Accountability Perspective." World Bank Research Observer 19(2), Fall 2004, p. 259-280.
Gemello, John and Jack Osman. "The Choice for Public and Private Education: An Economist's View," in Thomas James and Henry M. Levin, eds., *Public Dollars for Private Schools*, Philadelphia, PA: Temple University Press, 1983.
GeoLytics. 2002. *GeoLytics CensusCD 2000 Long Form Release 2.0*. East Brunswick, New Jersey.

Goldhaber, Dan. "An Endogenous Model of Public School Expenditures and Private School Enrollment." Journal of Urban Economics 46(1), July 1999, p. 106-128.

Goldstein, Gerald S. and Mark V. Pauly. "Tiebout Bias on the Demand for Local Public Goods." Journal of Public Economics 16(2), October 1981, p. 131-143.

Griffith, Daniel A. *Advanced Spatial Statistics: Special Topics in the Exploration of Quantitative Spatial Data Series*. Kluwer Academic Publishers, Dordrecht: 1988.

Hamilton, Bruce W. and Molly K. Macauley. "Determinants and Consequences of the Private-Public School Choice." Journal of Urban Economics 29(3), May 1991, p. 282-294.

Hayes, Kathy J. and Lori L. Taylor. "Neighborhood School Characteristics: What Signals Quality to Homebuyers?" Federal Reserve Bank of Dallas Economic Review 3, Fourth Quarter 1996, p. 2-9.

Helfand, Duke and Joel Rubin. "Few Families Transfer Out of Failing Schools." Los Angeles Times, Saturday, November 13, 2004. www.detnews.com/2004/schools/0411/14/schools-3995.htm.

Hite, Diane, Wen Chern, Fred Hitzhusen and Alan Randall. 2001. "Property Value Impacts of an Environmental Disamenity: The Case of Landfills." Journal of Real Estate Finance and Economics 22: 185-202.

Hoenack, Stephen A. "An Application of a Structural Model of School Demand and Supply to Evaluate Alternative Designs of Voucher Education Systems." Economics of Education Review 16(1), February 1997, p. 1-14.

Hoyt, William H. and Kangoh Lee. "Educational Vouchers, Welfare Effects, and Voting." Journal of Public Economics 69(2), August 1998, p. 211-228.

Jud, G. Donald and James M. Watts. "Schools and Housing Values." Land Economics 57(3), August 1981, p. 459-470.

Kelejian, Harry H. and Ingmar R. Prucha. "Prediction efficiencies in spatial models with spatial lags." University of Maryland College Park Economics Department working paper, 2004.

Krashinsky, Michael. "Why Educational Vouchers May Be Bad Economics." Teachers College Record 88(2), Winter 1986, p. 139-151.

Leik, R.F. 1966. "A Measure of Ordinal Consensus." Pacific Sociological Review 9, 85-90.

LeSage, James P. *The Theory and Practice of Spatial Econometrics*. February, 1999. www.spatial-econometrics.com.

LeSage, James P. *Spatial Econometrics*. http://www.spatial-econometrics.com/, December 1998.

LeSage, James P. "Regression Analysis of Spatial Data." Journal of Regional Analysis and Policy 27(2), 1997, p. 83-94.

Merrifield, John. *School Choices: True and False*. The Independent Institute, Oakland, CA: 2002.

Merrifield, John and David Salisbury. "The Competitive Education Industry Concept and Why it Deserves More Scrutiny." Cato Journal 25(2), Spring-Summer 2005, p. 181-195.

Ohio Department of Education. 2002. "EMIS Interactive Local Report Card School Year 2000-2001 District Level Data." Columbus, Ohio.

Ohio Department of Taxation. 2003. "2000 Millage Rates by School District." Columbus, Ohio.

Pace, R. Kelley. "Spatial Statistics Toolbox 2.0." FDELW2.m. February 15, 2003.

Pace, R. Kelley. "Performing Large Spatial Regressions and Autoregressions." Economics Letters 54(3), July 1997, p. 283-291.

Pace, R. Kelley and Ronald Barry. "Quick Computation of Spatial Autoregressive Estimators." Geographical Analysis 29(3), July 1997a, p. 232-247.

Pace, R. Kelley and Ronald Barry. "Sparse Spatial Autoregressions." Statistics and Probability Letters 33(3), May 1997b, p. 291-297.

Pace, R. Kelley, Ronald Barry and C.F. Sirmans. "Spatial Statistics and Real Estate." Journal of Real Estate Finance and Economics 17(1), July 1998, p. 5-13.

Pace, R. Kelley and James P. LeSage. 2005. "Interpretation of Parameter Estimates from Spatial Econometric Models." Louisiana State University Department of Finance working paper.

Palmquist, Raymond. "Estimating the Demand for the Characteristics of Housing." Review of Economics and Statistics 66(3), August 1984, p. 394-404.

Quigley, John M. "Nonlinear Budget Constraints and Consumer Demand: An Application to Public Programs for Residential Housing." Journal of Urban Economics 12(2), September 1982, p. 177-201.

Reiter, Michael and Alfons Weichenrieder. "Are Public Goods Public? A Critical Survey of the Demand Estimates for Local Public Services." Finanzarchiv N.F. 54(3), 1997, p. 374-408.

Rosen, Sherwin. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." Journal of Political Economy 82(1), January 1974, p. 34-55.

Rubinfeld, Daniel L., Perry Shapiro and Judith Roberts. "Tiebout Bias and the Demand for Local Public Schooling." Review of Economics and Statistics 69(3), August 1987, p. 426-437.

Sandy, Jonathan. "Evaluating the Public Support for Educational Vouchers: A Case Study." Economics of Education Review 11(3), September 1992, p. 249-256.

Seldon, Arthur. *The Riddle of the Voucher*. Hobart Paperback 21. London: Institute of Economic Affairs, 1986.

Tinbergen, Jan. "On the Theory of Income Distribution." Weltwirtschaftliches Archiv 77(2), 1956, p. 155-173.

Toma, Eugenia Froedge. "Public Funding and Private Schooling Across Countries." Journal of Law and Economics 39(1), April 1996, p. 121-148.

U.S. Environmental Protection Agency. 2002. "TRI On-site and Off-site Reported Releases (in pounds), for Facilities in All Industries, for All Chemicals, Ohio, 2000."

Walsh, Mark. "Supreme Court Upholds Cleveland Voucher Program." Education Week, June 27, 2002, http://www.edweek.org/ew/ew_printstory.cfm?slug=42voucher_web.h21.

Walsh, Mark. "Public Warming to Vouchers, Book Argues." Education Week, May 23, 2001, 20(37), p. 8.

West, Edwin G. "Education Vouchers in Principle and Practice: A Survey." The World Bank Research Observer 12(1), February 1997, p. 83-103.

Willms, J. Douglas and Frank Echols. "Alert and Inert Clients: The Scottish Experience of Parental Choice of Schools." Economics of Education Review 11(4), December 1992, p. 339-350.

Zabel, Jeffrey A. and Katherine A. Kiel. "Estimating the Demand for Air Quality in Four U.S. Cities." Land Economics 76(2), May 2000, p. 174-194.

---

[1] Some studies, like Gemello and Osman (1983), say private school vouchers would raise tax burdens; other studies, like Seldon (1986), say government savings could occur if the value of the voucher were less than the full cost of public schooling.

[2] This is just an illustration. The actual weights come from the product of wmat*wmat*θ, where wmat has elements i = 1/ (square root of the sum of the elements of the i-th row), and θ is the adjacency matrix from Voronoi tessellation.

[3] Thanks to Kelley Pace for his expertise on deciding the appropriate model for the demand regression, as well as for his help in running the alternative spatial models, which required too much for my computer to handle, even after upgrading from 2GHz to 4GHz of RAM.

[4] The public and private school proficiency measures differ in that Sheila Milligan of the Ohio Department of Education was only able to find math proficiency passage, whereas the public proficiency passage is based on more sections. However, this discrepancy is mitigated by the fact that passage rates on the math section are almost uniformly the lowest across school districts, so that passage of all sections by public schools more or less mirrors math proficiency passage.

[5] A previous version of the paper is available upon request that uses the implicit price of private schooling instead of private school tuition. That version of the paper uses 1991 data instead of 2000 data.
[6] The log-log functional form was the most appropriate for the public proficiency variable. The log-log functional form assumes that the percent change in house price is the same regardless of whether the percent change in proficiency passage occurs at high, low, or medium levels of proficiency passage, an assumption validated by Dills (2004).
[7] The elasticities from the spatial hedonics with statistically significant parameter estimates for rho should be adjusted by complex spatial feedback terms (Pace and LeSage, 2005), but the small magnitude of the rho estimates suggests that the adjustments in this case would not materially affect the elasticities.
[8] To see if there is statistical variation between the parameter estimates, I ran a pooled OLS hedonic regression with PUBLIC PROFICIENCY and an interaction term between PUBLIC PROFICIENCY and dummy variables for each urban area (omitting Akron). The signed t-ratios of the interaction terms are as follows: -2.08 for Cincinnati, 28.2 for Cleveland, 5.65 for Columbus, -25.6 for Dayton, -2.08 for Toledo, and -35.09 for Youngstown.
[9] The elasticities are based on Hayes and Taylor (1996) North Dallas math proficiency Model 2; Clapp, Nanda and Ross (2005) town or tract fixed effect models, Downes and Zabel (2002) 8th grade reading proficiency pooled regression with neighborhood variables, and Figlio and Lucas (2004) Iowa Test of Basic Skills 4th grade math scores.
[10] The PRICE PUBLIC variable for the OLS and LIML models is calculated from OLS hedonic models like Equation (1). The OLS parameter estimates of LN PUBLIC PROFICIENCY are 0.263 for Akron, -0.058 for Cincinnati, 0.230 for Cleveland, 0.056 for Columbus, 0.203 for Dayton, 0.102 for Toledo, and 0.178 for Youngstown; all are statistically significant at conventional levels.
[11] All elasticities are reported at the variable means, unless otherwise noted.
[12] Thanks to Kelley Pace for programming the algorithm that creates the unique dual spatial weight matrices, running the models on his fast home computer, and advising me on proper model selection.
[13] The OLS hedonic parameter estimates for LN EXPENDITURES are -0.183 for Akron, 0.297 for Cincinnati, 0.133 for Cleveland, 0.260 for Columbus, -0.372 for Dayton, 0.229 for Toledo, and -0.295 for Youngstown, all statistically significant at conventional levels.
[14] The general spatial model hedonic parameter estimates for LN EXPENDITURES are -0.237 for Akron, 0.283 for Cincinnati, 0.145 for Cleveland, 0.162 for Columbus, -0.394 for Dayton, 0.211 for Toledo, and -0.241 for Youngstown, all statistically significant at conventional levels.
[15] The full sample correlation between the number of bedrooms and income is 0.35.
[16] The parameter estimates are 0.0080 for TUITION, -3.16 for PUBLIC PROFICIENCY, and 0.115 for the interaction term INCOME*QUANTITY PUBLIC. The 25th percentile INCOME is 3.82 and the 75th is 6.27.
[17] See also a theoretical model by Hoyt and Lee (1998) which includes a calculation of the magnitude of the elasticity of private school enrollment necessary for vouchers to reduce taxes.
[18] Many of these programs are discussed in West (1997), Toma (1996), Willms and Echols (1992), and Gauri and Vawda (2004).