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JOURNAL OF HOUSING RESEARCH VOLUME **26** ISSUE **2**

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Beyond Standardized Test Scores: The Impact of a Public School Closure on House Prices

Alicia Rosburg, Hans Isakson, Mark Ecker, and Tim Strauss

Abstract

In most studies, standardized test scores are used as a proxy for school quality. Standardized test scores, however, may not fully capture the value of a public school to the households who live in the school's attendance zone. We use the sudden closure of a well-performing public school in Iowa to estimate this value. Holding other things constant, we find that the school added 6.8% (about $9,000 for the mean house price) to the value of houses in the attendance zone over and above any effect associated with standardized test scores.

Housing studies consistently demonstrate that higher quality schools have a positive impact on nearby housing values. These findings emerge from studies spanning several countries, modeling techniques, and levels of education (Black, 1999; Brasington, 1999; Downes and Zabel, 2002; Figlio and Lucas, 2004; Kane, Riegg, and Staiger, 2006; Clapp, Nanda, and Ross, 2008; Black and Machin, 2011; Machin, 2011; Nguyen-Hoang and Yinger, 2011; Dhar and Ross, 2012; Gibbons, Machin, and Silva, 2013).[1] In most of these studies, standardized test scores are used as a proxy for school quality and the marginal change in house prices associated with a marginal change in test scores is estimated, holding other things that affect house prices constant.[2]

Estimations of the impact of a school on house prices are used in only a few studies by taking advantage of quasi-experimental settings, usually created by attendance rezoning, school closings/openings, school consolidations, etc. (e.g., Bogart and Cromwell, 2000; Ries and Somerville, 2010; Feng and Lu, 2013; Wada and Zahirovic-Herbert, 2013). The rarity under which these situations occur and the availability of sufficient data have limited the number of empirical studies of this type. However, when sufficient data exist, quasi-experimental settings are particularly well-suited for analysis using a difference-in-difference (DiD) approach.[3] For example, using a DiD approach, Bogart and Cromwell (2000) find a 9.9% reduction in house values from the redistricting of an Ohio school district from nine to six elementary schools. Also using the DiD approach, Ries and Somerville (2010) find negative effects for a subset of house prices from a school rezoning in Vancouver.[4]

We add to this small body of literature by evaluating the sudden closure of a single, well-performing public school in Cedar Falls, Iowa. Beyond the suddenness of the closure, this study differs from the previous literature in that the school's closure was the result of exogenous changes in state funding, rather than under-performance or declining enrollment. We take advantage of this unique quasi-experimental setting to estimate the impact of a school on house prices beyond that measured by standardized test scores or other endogenous factors.

Quasi-Experimental Setting: Closure of Malcolm Price Laboratory

Our quasi-experimental event was created by the sudden closure of a public school—the Malcom Price Laboratory School (MPLS) at the University of Northern Iowa (UNI) in Cedar Falls, Iowa.[5] MPLS was established in 1914, to be housed within existing UNI buildings. In 1945, the state approved funding for the construction of a new building to house the laboratory school and other facilities. After postwar delays, the university purchased land for the school in the fall of 1948. Construction of the school began in the fall of 1950, and the first building (an elementary school) was completed in the summer of 1953. A high school building was completed in the fall of 1955. An attendance zone was established that overlapped the Cedar Falls Public School District, such that households located within the attendance zone had the option to send their children to MPLS or the designated Cedar Falls school. This option was attached to the house and was not transferable.

Similar to other laboratory schools, MPLS had two major objectives.[6] First, to provide the best education possible to students attending the school. Second, to provide a world-class laboratory experience, in which teaching innovations were implemented and evaluated, and where teachers in training could practice their trade under the watchful eye of master teachers. Over time, MPLS gained the reputation of providing a high-quality education with small classes and multiple instructors in each classroom.

Attempts were made to close MPLS in 1971, 1986, 1989, and 2002. These attempts were derailed, in part, by the efforts of parents and alumni. On February 16, 2012, UNI President Ben Allen sent an email to university employees stating that several programs, including MPLS, were under review for possible cuts. The next day, the local newspaper reported, based on an interview with Allen, that ''specific details about those cuts, consolidations or closures have yet to be finalized'' (Ericson, 2012b). Allen cited several issues regarding MPLS, including budget considerations, the cost of renovating or replacing the building, and the idea of moving to a ''virtual model'' of teacher education. Six days later (February 22), Allen announced to teachers, parents, and students that MPLS would be closed at the end of the academic year, pending approval of the Iowa Board of Regents. Five days later (February 27), the Regents approved Allen's recommendation in a telephone meeting; Iowa Governor Terry Branstad expressed his support for the decision the next day. In a matter of 12 days, the school went from a business-as-usual routine to the reality of certain closure in a few months. Parents were notified that their decisions regarding the enrollment of students at surrounding schools for the following fall would need to be made by April 16. Demolition of the MPLS classroom building began after the school year ended (summer 2012). Rarely does one witness such a quick decision by a public board with such a geographically focused impact.[7]

While the school operated, parents residing within the MPLS attendance zone had the option to send their children to the laboratory school or the designated Cedar Falls public school. Students living outside the MPLS zone were allowed to enroll into MPLS subject to more restrictive conditions and with the possible payment of tuition and fees.[8] In other words, prior to its closure, households within the MPLS attendance zone owned an option that households outside the zone did not. Because this option was attached to the house and was not transferable, this option can be treated as any other neighborhood amenity of the house. According to Rosen's (1974) hedonic theory, if residents valued the ''MPLS option,'' it would be capitalized into house prices, and the sudden removal of this option would reduce the value of houses within the attendance zone.

Anecdotal evidence suggests that residents did value the MPLS option. For example, some parents moved into the attendance zone so that their children could attend the school (Linh, 2013). In one high-profile case, several parents were accused of falsely claiming their children lived within the MPLS zone to ensure their attendance and avoid paying tuition (Reinitz, 2010). Residents of the MPLS attendance zone often expressed their convictions that the school was a valuable part of the neighborhood, and many parents believed that the innovative teaching methods used at MPLS and access to UNI resources prepared students well for post-secondary education. Consequently, residents within the zone felt that the values of their homes were enhanced by the MPLS option (i.e., MPLS created a neighborhood amenity) (Ericson, 2012a). This perception was reinforced by the mention of location within the MPLS zone as a selling point in real estate listings. After the closure announcement, residents expressed concerns about the impact on property values and more generally the neighborhood's character. The President of the Waterloo-Cedar Falls Board of Realtors similarly suggested that MPLS had increased neighborhood property values but by an uncertain amount (Ericson, 2012a). If this anecdotal evidence is correct, house prices within the MPLS zone should reflect this additional value (i.e., beyond standardized test scores); this value may have resulted from a number of factors, such as innovative MPLS curriculum, community pride, and enhanced reputation.

Whether or not house values inside the attendance zone were enhanced by the school is the empirical question we address in this study. The sudden closure of the school creates a quasi-experimental opportunity in which house prices before and after the closure, as well as inside and outside the attendance zone, can be examined for evidence of a positive external effect associated with the school, holding other things that affect housing prices constant.

The MPLS closure differs from most school closings analyzed in the literature in that under-performance and/or declining enrollment did not contribute to its closure; the closing of MPLS was driven largely by exogenous changes in state funding, especially university budgeting decisions.[9] Further, our analysis isolates a school effect that is not clouded by variations in school quality as measured by standardized test scores. We found no statistical difference in test scores between MPLS and the Cedar Falls public elementary schools that overlapped the MPLS attendance zone.[10] Therefore, we use the difference in difference (DiD) approach to model and estimate the effect of the closure of a public K–12 school over and above any effect associated with standardized test scores.

Modeling the Effects of a School Closure

We examine the effect of the MPLS closure using a quasi-experimental, difference-in-difference (DiD) approach. The Cedar Falls housing market is used as a pseudo-laboratory in which the quasi-experiment occurs. The DiD approach is a popular technique for examining the impact of an event on housing prices.[11] It has also been extensively used in the valuation of school quality and performance; Black and Machin (2011) and Nguyen-Hoang and Yinger (2011) provide detailed overviews of this literature.

To properly employ a pure DiD, one would need test and control groups consisting of the *same* members (e.g., houses) before and after some treatment. Members of the test group receive the treatment, while members of the control group receive a placebo. In the double-blind version, the researcher does not know which members receive a placebo, and the group members do not know if they receive a placebo. In the DiD approach used in many housing market studies, the members of both groups are *not the same* before and after the treatment (event), because, typically, the same (identical) houses do not sell just before and again right after the event. Instead, researchers statistically control for differences in the characteristics of the houses before and after the event and within the test and control groups. We use this approach for our analysis of the housing sales in the MPLS attendance zone.

The treatment event of interest is the closure of MPLS, and houses located within the MPLS attendance zone constitute the test group. The control group consists of an adjacent neighborhood located in central Cedar Falls (CCF). The CCF and MPLS neighborhoods represent a relatively homogeneous housing submarket within Cedar Falls.[12] Most of the older homes within Cedar Falls are located within these two neighborhoods. The CCF neighborhood is defined using natural neighborhood boundaries; namely, three of the four boundaries (west, east, and north) are defined as main roads passing through the city. The fourth boundary (south boundary) lies along the northern boundary of the MPLS attendance zone. For comparative purposes, the boundaries for the entire city of Cedar Falls, CCF, and MPLS are displayed in Exhibit 1 (along with housing sales and other points of interest). Exhibit 2 provides a zoomed in view of the MPLS attendance zone and CCF control group.

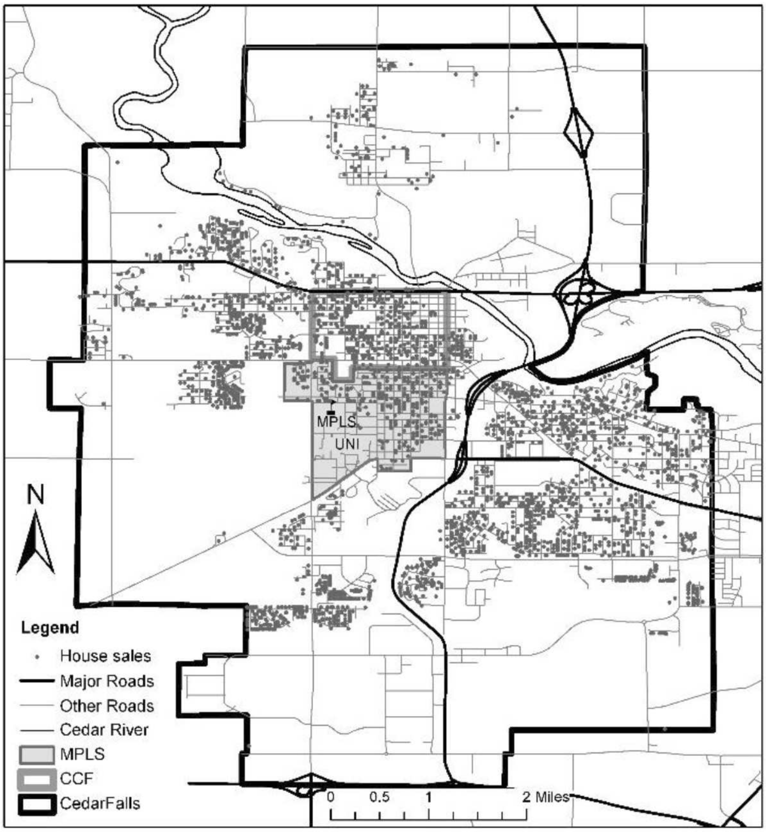
To implement the DiD approach, we create three indicator variables: *MPLS* equals 1 if the house is in the MPLS attendance zone, *After* equals 1 if the house sold after April 1, 2012,[13] and *DiD* is the difference-in-difference variable or the product of the other two indicator variables. The coefficient on the *DiD* variable (δ) is our estimate of the school closure effect and the focus of this study.

We use a hedonic model that can be expressed in general terms as:

$$Y_i = \alpha_1 MPLS_i + \alpha_2 After_i + \delta DiD_i + \boldsymbol{\beta X_i} + \varepsilon_i, \quad \text{for } i = 1,\dots, n, \tag{1}$$

where Y_i is the log(price) for the i^{th} sale, $MPLS_i$ is the MPLS indicator variable for the i^{th} sale, $After_i$ is the indicator variable if the i^{th} sale is after the MPLS closure, α_1 is the parameter estimate of the marginal effect of being in the MPLS zone, α_2 is the parameter estimate of the marginal effect of time after the MPLS closure, $DiD_i = MPLS_i \times After_i$ is the DiD interaction factor for the i^{th} sale, δ is the *DiD* parameter estimate, $\boldsymbol{X_i}$ is a vector of other independent variables that we expect to naturally influence house prices for the i^{th} sale, $\boldsymbol{\beta}$ is a vector of sale-specific parameters (including intercept) associated with the other independent variables, and ε_i is the error term associated with the i^{th} sale. Depending on our model specification, the vector $\boldsymbol{X_i}$ contains structural, neighborhood, and/or other characteristics (e.g., locational, temporal, and macroeconomic characteristics). A complete variable list and specific details of each variable are discussed

Exhibit 1. Map of Cedar Falls

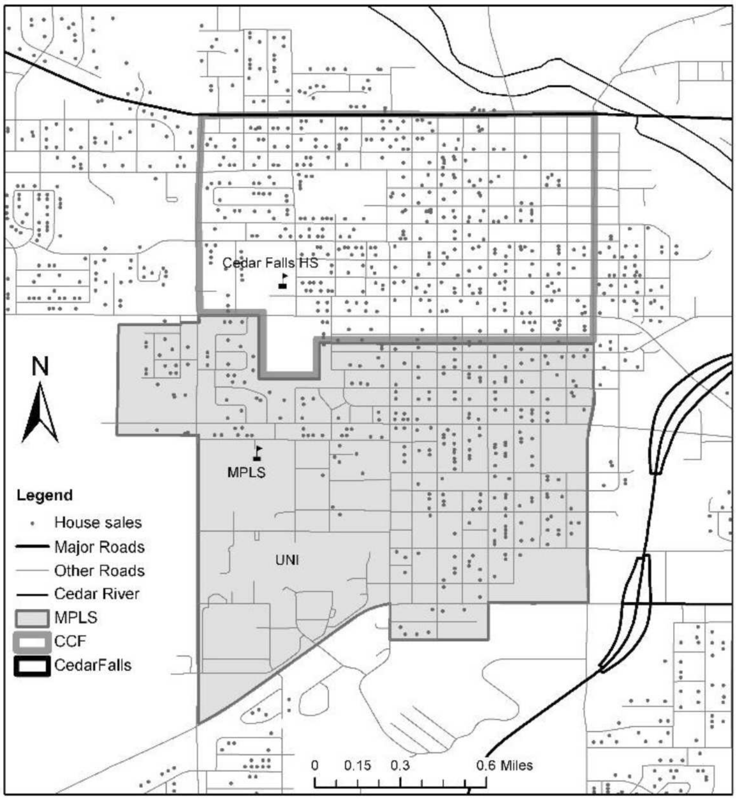


This is a map of the city of Cedar Falls, Iowa and includes boundaries for all Cedar Falls, CCF, and Cedar Falls.

in the data section. Lastly, to correct for inflation over time, we follow Bogart and Cromwell (2000) and deflate sale prices using a repeat-sales annual housing price index.[14] This detrending technique converts the nominal selling price into a real price, thus removing the need to include time as an independent variable in any subsequent model. The resultant housing price indexes for 2009 to 2013 are reported in Exhibit 3.[15]

To estimate the parameters of equation (1), we include an error or disturbance term, ε. In standard ordinary least squares (OLS) regressions, it is assumed that $\varepsilon \sim N(0, \gamma^2)$ and where constant variance is understood; γ^2 represents the constant variance parameter, after accounting for all values of the covariates. When dealing with spatial data, such as housing sales, the potential exists for the OLS parameter estimates to be biased, especially any spatial distance parameter estimates for the independent variables (e.g., distance to school, etc.). Visual examination of an empirical variogram of the OLS residuals in equation (1) reveals the presence of spatial correlations.[16] Consequently, the OLS technique will produce biased parameter estimates (Cressie, 1993). To remove this source of bias, we adopt the geostatistical technique used by Dubin (1992), Basu and Thibodeau

Exhibit 2. Map of CCF and MPLS



This map is a zoomed in view of the central Cedar Falls (CCF) control group and the MPLS attendance zone located in Cedar Falls, Iowa.

Exhibit 3. Housing Price Index

Year	Index
2009	1.088
2010	1.111
2011	1.100
2012	1.084
2013	1.144

Notes: This table reports housing price indexes for 2009–2013 based on repeat sales in Cedar Falls from 2006 to 2013. The base year is 2006. Year 2013 only includes sales through July 31, 2013.

(1998), and Tu, Sun, and Yu (2007) and incorporate spatial correlation into the error term of our model.

In spatial linear models, it is assumed that the errors are not independent; that is, two comparable houses that are closer in space sell for a more similar price than two comparable houses farther apart. For example, houses located near each other are also near the same neighborhood amenities and/or disamenities. In this case, the selling prices of nearby, comparable houses tend to be more correlated than comparable houses farther apart. We build spatial correlation into equation (1) by specifying the error term as follows:

$$\varepsilon \sim N(0, \tau^2 + \sigma^2), \tag{2}$$

where τ^2 is called the ''nugget,'' i.e., a micro-scale or measurement error variability, in the geostatistical literature (Cressie, 1993). The sum $\tau^2 + \sigma^2$ in equation (2) is termed the spatial variability of the spatial process or ''sill'' (the variability of the house prices after adjusting for individual house characteristics). Finally, for two house sales with errors ε_i and ε_j, their spatial correlation is modeled as a function of their Euclidean distance apart, d_{ij}. Specifically, we adopt the spherical correlation structure, i.e.,

$$Corr(\ln(\varepsilon_i), \ln(\varepsilon_j)) = \frac{1}{2}(\phi^3 d_{ij}^3 - 3\phi d_{ij} + 2) \quad \text{if } d_{ij} \leq \frac{1}{\phi}. \tag{3}$$

The parameter ϕ directly controls the spatial correlation in the dataset and is termed the ''range'' [technically $1/\phi$ is the exact value of the range in equation (3); see Ecker (2003) for the spherical correlation structure]. Thus, any two houses that are separated by a distance of more than the range have selling prices that are essentially uncorrelated.[17] Modeling the spatial correlation of house prices in this way corrects for locational influences not included in the mean structure of the model.

Data and Empirical Approach

The primary data for our analysis consists of housing sales that occurred in the MPLS attendance zone (test group) and CCF neighborhood (control group) between January 1, 2009 and July 31, 2013. A starting date of January 1, 2009 was selected to minimize any effects from previous closure attempts (the most recent closure attempt was in 2002) and other events just prior to 2009 (e.g., the Iowa legislature changed the designation of MPLS in 2008 to a ''statewide research and development school''). The Cedar Falls housing market was not seriously affected by the U.S. housing market decline that started in 2006. Rather, trend analysis suggests that the Cedar Falls housing prices actually increased over this period.[18] The ending date of July 31, 2013 was set due to data availability. The time frame of our analysis (January 1, 2009 to July 31, 2013) provides adequate data to capture the effect of interest and is consistent in length to the time frames used by Ries and Somerville (2010), Feng and Lu (2013), and Wada and Zahirovic-Herbert (2013).

Housing selling prices and characteristics for each house were obtained from the Black Hawk County Board of Supervisors.[19] These data include coordinates (State Plane Coordinate System, Iowa North, NAD 1983, in feet), which were used to generate points in a geographic information system (GIS) for integrating spatial data, creating spatially-based variables, and analyzing results.[20] A supplemental data set from the City of Cedar Falls Fire Department was used to identify houses classified as rental properties. Exhibit

Exhibit 4. Summary Statistics

	MPLS		CCF		Rest of Cedar Falls[a]	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Dependent Variable						
Sale amount[b]	132,076	34,177	120,457	38,175	185,744	95,912
Structural Characteristics						
Main living area	956	291	871	255	1,164	413
Non-main living area	384	442	481	455	373	555
Deck square feet	111	126	113	132	166	135
Number of fireplaces	0.40	0.51	0.26	0.45	0.57	0.56
Garage square feet	376	212	340	218	512	245
Porch square feet	78.7	84	81.4	83	72.8	81
Age of house at sale	66.5	30	80.6	28	40	31
Lot size	0.20	0.06	0.18	0.07	0.29	0.17
Number of stories	1.38	0.48	1.45	0.49	1.36	0.48
Number of bathrooms	1.17	0.43	1.11	0.32	1.25	0.47
Number of bedrooms	2.85	0.79	2.89	0.82	3.10	0.85
Rental	0.40	0.49	0.33	0.47	0.09	0.29
Neighborhood Characteristics						
Median house value	171,701	40,967	134,759	12,372	173,581	43,388
Median rent value	667	153	788	315	705	282
Median year built	1,961	16.4	1,947	5.84	1,970	16.7
4^{th} grade test score	641.3	15.5	647.4	40.5	641.5	17.1
Other Variables						
Distance to UNI	3,364	757	6,466	1,056	9,021	3,002
Summer sale	0.28	0.45	0.30	0.46	0.28	0.45
Employment	90,191	981	90,095	969	90,095	1,002

Notes: This table reports summary statistics for the time series of house sales in all Cedar Falls, central Cedar Falls (CCF) and the MPLS attendance zone from January 1, 2009 to July 31, 2013.
[a] Includes all house sales in Cedar Falls except those located in the MPLS attendance zone.
[b] Represents the detrended selling price.

4 lists the descriptive variables used for each transaction. Also reported in Exhibit 4 are the variable means and standard deviations for sales in the MPLS attendance zone (N = 179), the CCF control neighborhood (N = 255), and the rest of Cedar Falls (N = 1702).[21] Exhibit 5 reports frequency statistics by year and spatial-temporal zone (i.e., *MPLS, After, DiD*). For the sample period, the counts of housing sales are relatively consistent across the years.

The summary statistics in Exhibits 4 and 5 provide support for our choice of the CCF neighborhood as a control group instead of the rest of Cedar Falls. The CCF neighborhood is similar to the MPLS attendance zone for most structural and neighborhood characteristics. For example, the average house sold in the rest of Cedar Falls was much larger (e.g., lot size, main living area, garage size, deck size) than the average house sold in either the CCF or MPLS areas. Further, houses sold in the CCF and MPLS areas were more likely to be rentals (33% and 40%, respectively) than the average house sold in the rest of Cedar Falls (9%). Because of these differences, the average selling price for the rest of Cedar Falls was significantly higher than the average selling price in the CCF and MPLS areas.

Exhibit 5. Frequency (%)

Variable	MPLS	CCF	Rest of Cedar Falls[a]
Year 2009	31 (17.3%)	45 (17.6%)	340 (20.0%)
Year 2010	35 (19.6%)	52 (20.4%)	327 (19.2%)
Year 2011	37 (20.7%)	47 (18.4%)	312 (18.3%)
Year 2012	48 (26.8%)	66 (25.9%)	423 (24.9%)
Year 2013[b]	28 (15.6%)	45 (17.6%)	300 (17.6%)
Zone			
MPLS	179 (100%)	—	—
After	68 (38%)	100 (39%)	649 (38.1%)
DiD product	68 (38%)	—	—

Note: This table reports frequency values for time and zone variables for the time series of house sales in all Cedar Falls, central Cedar Falls (CCF), and the MPLS attendance zone between January 1, 2009 and July 31, 2013.
[a] Includes all house sales in Cedar Falls except those located in the MPLS attendance zone.
[b] Year 2013 only includes sales through July 31, 2013.

The average house selling price between 2009 and 2013 was approximately $132,000 in MPLS and $120,000 in CCF (2006$). On average, a house sold in either of these neighborhoods had about 2.9 bedrooms and 1.2 bathrooms. Houses sold in the CCF were slightly older at the time of sale (81 years) compared to houses in MPLS (67 years), which most likely accounts for the $12,000 difference in marginal average selling prices for the two regions. Houses in MPLS were more likely to be rentals, had slightly larger lot sizes, more main living area, number of fireplaces, and garage square feet than the average house sold in CCF. On the other hand, houses sold in CCF had more non-main living area, larger porches and decks, and were more vertical (i.e., more stories). However, most of these differences are minimal, indicating that the houses sold in CCF were very similar to the houses sold in the MPLS zone. Nonetheless, we include the traditional housing characteristics for additional controls.

Census boundary files obtained from the Iowa Department of Natural Resources (DNR) GIS data clearinghouse were used to attach, through a spatial join, census identification numbers to the house sales. These identifiers were then used to attach neighborhood characteristics from the 2007–2011 American Community Survey to the house sales based on Census block group membership. Neighborhood characteristics include median house value, median rental value per month, and median year built. The CCF and MPLS neighborhoods are small in geographic scope and more homogeneous than larger-sized markets, thereby limiting our need to control for large variations in neighborhood characteristics (Clapp, Nanda, and Ross, 2008).

Another neighborhood characteristic included is a measure of school quality. Boundaries for elementary school attendance zones were provided by the Iowa Northland Regional Council of Governments. These include the boundaries for the MPLS attendance zone, which were also cross-checked with UNI archival documents. Spatial joins were used to attach school attendance zones to each house sale. Test scores for each elementary school were taken from the Iowa Tests of Basic Skills. The *4th grade test score* is the sum of the fourth grade average National Standard Score (NSS) for reading, math, and science; the score varies by year and elementary school attendance zone.[22] With little variation in school quality metrics between MPLS and the Cedar Falls public schools, we do not expect housing prices to be responsive to measurable school quality differences (Black, 1999). However, we include the test score measure to formally test this expectation.

To control for any university-related effect, straight-line/Euclidean distances were computed in GIS between each house sale and the Campanile (a UNI landmark near the center of campus). *Employment*, measured as monthly employment in the Waterloo-Cedar Falls metropolitan area (U.S. Bureau of Labor Statistics, 2013), is included to capture variation in general economic conditions. Finally, we include a binary seasonal variable. *Summer sale* controls for potentially different housing prices during the summer and takes a value of one if the house was sold between June 1 and August 15.

To verify the robustness of our results to the set of independent variables, we estimate the parameters of equation (1) using nested hedonic models. For each model, the test group consists of 179 housing sales within the MPLS attendance zone before and after the closure and the control group consists of the 255 sales in the CCF neighborhood. In the first model, we consider only ''zone'' variables (i.e., DiD variables) and structural house characteristics. The second model includes neighborhood variables. The third model includes other variables that we believe might influence the Cedar Falls housing market—distance to UNI, summer sale, and local employment. For each model, the natural log of selling price is regressed on the relevant independent variables, while simultaneously estimating the spatial correlation parameters in equations (2) and (3) using an iterative maximum likelihood process (*Proc Mixed* contained in SAS). If house prices in the MPLS attendance zone have been adversely affected by the closure of MPLS (holding other things constant), then we would expect the *DiD* parameter estimate to be negative. We also expect the house characteristic and neighborhood characteristic parameter estimates to be positive (with the exception of age at sale, rental status, and median year built) and the distance to UNI coefficient estimate to be negative.

Results

SAS *Proc Mixed* maximum likelihood results and spatial correlation estimates for the three models are provided in Exhibit 6. Physical characteristics have the expected effects on house prices. In all models, housing sale prices increase with main living area, non-main living area, deck size, number of fireplaces, garage size, porch size, lot size, number of stories, number of bathrooms, and number of bedrooms. Most of these variables are statistically significant across all models. Number of bedrooms, however, is not statistically significant in any model and the number of bathrooms is only significant at the 10% level for the last two models. Lot size is statistically significant at the 10% level in the structural variables only model and structural and neighborhood model but is not significant in the full model. As expected, housing prices are negatively related to the age of the house at sale and rental status. Both of these variables are strongly significant across all models.

For neighborhood characteristics, the median year built has a negative effect on housing sale prices and is the only neighborhood variable that is statistically significant (5% level).

Exhibit 6. Regression Results

Variable	Structural Variables Only (1) Coeff.	t-stat.	Structural & Neighborhood Variables (2) Coeff.	t-stat.	Full Model (3) Coeff.	t-stat.
Intercept	11.13		18.70		18.13	
Zone						
MPLS	0.079***	3.37	0.110***	3.91	0.053	0.21
After	0.101***	4.60	0.106***	4.65	0.111***	4.49
DiD	−0.072**	−2.12	−0.069**	−2.03	−0.068**	−2.01
Structural Characteristics						
Main living area	0.0004***	8.14	0.0004***	7.87	0.0004***	7.90
Non-main living area	0.0002***	6.63	0.0002***	6.61	0.0002***	6.48
Deck square feet	0.0001*	1.91	0.0001*	1.87	0.0001*	1.72
Number of fireplaces	0.0510**	2.36	0.0505**	2.34	0.0484**	2.23
Garage square feet	0.0001***	3.37	0.0001***	3.34	0.0002***	3.52
Porch square feet	0.0004***	3.45	0.0004***	3.31	0.0004***	3.35
Age of house at sale	−0.0030***	−6.67	−0.0034***	−6.86	−0.0034***	−6.92
Lot size	0.2941*	1.92	0.2882*	1.88	0.2236	1.44
Number of stories	0.0494**	2.14	0.0530**	2.30	0.0557**	2.41
Number of bathrooms	0.0365	1.50	0.0435*	1.78	0.0412*	1.67
Number of bedrooms	0.0212	1.60	0.0182	1.37	0.0185	1.39
Rental	−0.1240***	−6.38	−0.120***	−6.18	−0.1250***	−6.37
Neighborhood Characteristics						
Median house value			0.0004	0.68	0.0001	0.23
Median rent value			0.0001	1.38	0.0000	0.76
Median year built			−0.0037**	−2.51	−0.0033**	−2.25
4^{th} grade test score			−0.0007	−0.96	−0.0008	−1.19
Other Variables						
Distance to UNI					−0.0000*	−1.71
Summer sale					−0.0260	−1.32
Employment					0.0000	0.12
−2 Res Log Likelihood	−157.3		−111.4		−69.0	
Spatial Correlation Parameter *Estimates*						
Nugget	0.0125		0.0135		0.0134	
Sill	0.0301		0.0296		0.0294	
Range	223.1 feet		226.2 feet		220.7 feet	
Marginal effect of closure on mean house in MPLS (2006$)	−$9,509		−$9,113		−$8,981	

Notes: This table reports SAS *Proc Mixed* regression results where the (detrended) natural log of selling price is regressed on independent variables while simultaneously estimating the spatial correlation parameters. Column (1) reports the regression results (and their *t*-statistics) when only zone variables and structural variables are included. The regression for the results in column (2) include the neighborhood variables. The regression for the results in column (3) include other variables that we believe might influence the Cedar Falls housing market. In all models, the test group consists of housing sales in the MPLS attendance zone and the control group consists of sales in the CCF neighborhood between January 1, 2009 and July 31, 2013. Log-likelihood values are reported for each model, as well as the marginal effect of the MPLS closure on the mean house in MPLS (2006$).

*Significant at $p < 0.10$, according to a *t*-test.

**Significant at $p < 0.05$, according to a *t*-test.

***Significant at $p < 0.01$, according to a *t*-test.

As expected, the 4th grade test score effect is insignificant; the full model results are robust to removal of the test score variable.[23] Inclusion of other variables (i.e., distance to UNI, summer sale, and employment) provides a slightly improved model fit but yields similar overall results. Proximity to UNI has a positive effect on house prices and is significant at that 10% level. Summer sale and local employment are not significant.

The spatial variability parameter estimates are reported at the bottom of Exhibit 6. Each of the three models has a total variability or sill between 0.0294 and 0.0301, while the model with only physical and neighborhood variables has the highest pure error or nugget of 0.0135. The range of spatial correlation is also fairly consistent across models (221 to 226 feet). Thus, the selling prices of pairs of houses separated by more than roughly 225 feet are essentially uncorrelated.

The coefficient of interest, the *DiD* parameter estimate, is negative and statistically significant, suggesting that the closing of MPLS had a negative effect on house prices within the attendance zone; this finding is robust across all three models. The negative effect ranges from 6.8% in the full model to 7.2% in the structural variables only model or $8,891 to $9,509 (2006$) at the mean house value within the attendance zone.[24] These effects are consistent with, but slightly smaller than, the negative effects (9.9%) reported in Bogart and Cromwell (2000). However, Bogart and Cromwell's analysis included multiple school closings, changes in school racial composition, and the introduction of a bus transportation system.

Our results suggest that MPLS enhanced the value of houses in its attendance zone, over and above any value associated with standardized test scores. This is consistent with the sociology literature where others have pointed out that schools may provide a neighborhood amenity value beyond standardized test scores. For example, elementary and secondary schools are frequently a center for community integration and a source of community identity and spirit (Sell and Leistritz, 1997). Schools serve as neighborhood anchors that provide social capital (Besser, Recker, and Agnitsch, 2008), reinforce neighborhood socioeconomic growth, and offer social and educational stability for students (Burdick-Will, Keels, and Schuble, 2013).

We expand on this literature by quantifying the neighborhood amenity effect. Specifically, the 6.8% to 7.2% reduction in house prices represents a lost neighborhood amenity associated with MPLS. This reduction, which was previously capitalized into house prices, represents the value of the school choice option (i.e., private value) plus any external benefits (i.e., social value) associated with MPLS.

Conclusion

Malcolm Price Laboratory School (MPLS) was a well-performing, public school in Cedar Falls, Iowa that was suddenly closed in 2012. Prior to the school's closure, residents in the school's attendance zone owned the option to send their children to MPLS or the designated Cedar Falls public school. The suddenness of the school's closure provides a unique quasi-experimental opportunity in which housing prices can be examined for evidence of external effects associated with the school over and beyond any effect associated with standardized test scores. According to hedonic price theory, all else equal, housing values in the MPLS attendance zone should decrease after the MPLS closure, if the option to send one's children to MPLS had value.

We used a difference-in-difference approach and housing sales data for January 1, 2009 to July 31, 2013 to evaluate the effects associated with the school and its closure. The sales in the MPLS attendance zone were the test group and the control group included sales in an adjacent neighborhood located in central Cedar Falls with similar housing characteristics to houses in the MPLS zone. The closure of this school is unique from other school closures analyzed within the literature in that it was not closed due to under-performance and/or declining enrollment; the closing of MPLS was driven by exogenous changes in state funding and university budgeting decisions. Therefore, school quality and local economic issues do not confound our empirical analysis.

We find that the closure of MPLS had a negative effect on house prices within the attendance zone. Depending on model specification, the school's closure reduced house values by 6.8% to 7.2%, or between $8,981 and $9,509 (2006$) at the mean house value. In other words, our results are consistent with the proposition that the MPLS option had value beyond that measured by standardized test scores. These results have important implications for policymakers as they weigh the benefits and costs of maintaining, closing or consolidating public schools. Further, for researchers interested in modeling the effects of schools on house values, our results suggest that a school-related hedonic analysis should recognize the potential value above and beyond any effect associated with standardized test scores (e.g., neighborhood amenity value).

Endnotes

1 For a relatively comprehensive overview of the economics literature on housing values and school performance, see Black and Machin (2011) or Nguyen-Hoang and Yinger (2011).

2 Test scores are the most commonly used proxy for school quality in hedonic models. However, alternative measures such as value-added or subjective measures (e.g., parent satisfaction, child happiness) have gained popularity in recent years. The evidence is mixed as to whether these measures are capitalized into housing values (Brasington and Haurin, 2006; Gibbons and Silva, 2011; Gibbons, Machin, and Silva, 2013).

3 The difference-in-difference (DiD) statistical technique estimates the outcome (e.g., changes in house prices) of a treatment (e.g., school closure), and is designed to be applied in (quasi) experimental settings that include a test and control group with similar subjects (e.g., houses) both before and after the treatment.

4 The negative effect was only statistically significant for houses likely to be purchased by upper-income families.

5 Information about the history of MPLS is from Peterson et al. (2012).

6 Over 100 laboratory schools are currently associated with colleges and universities worldwide (International Association of Laboratory Schools, 2014).

7 The National Clearinghouse for Educational Facilities (McMilin, 2010, p. 2) recommends that "a decision to close a school should be made as early as possible in the school year, but no later than December."

8 Some school districts allowed their students to enroll freely in MPLS, while others did not. Students residing in the Cedar Falls Public School District (outside the MPLS zone) were required to pay tuition and fees to attend MPLS.

[9] The budget decisions at UNI did not result in a significant loss of academic, administrative or staff positions. However, any (non-MPLS) effects from UNI budgetary decisions are expected to be felt uniformly throughout Cedar Falls and not be isolated to the MPLS attendance zone. In other words, the closure of MPLS is the only change caused by the budgetary decisions that we expect to affect the MPLS zone differently than houses elsewhere in the city.

[10] Pair-wise multiple comparisons failed to reject the hypothesis that test scores were equal at the 10% level for 2004–2011. Although not testable with our dataset, it is possible that MPLS may have created competition (and therefore market pressure) for the Cedar Falls public schools, which incentivized them to maintain a certain quality level (and vice versa); evidence of such an effect has been found in cities that opened charter schools (Jinnai, 2011).

[11] Recent examples of the DiD approach include studies on the effects of new transportation stations (Gibbons and Machin, 2005), new sports stadiums (Tu, 2005), subsidized housing (Schwartz, Ellen, Voicu, and Schill, 2006), community gardens (Voicu and Been, 2008), aquatic invasive species (Horsch and Lewis, 2009), LUST sites (Zabel and Guignet, 2012), and wind energy facilities (Hoen et al., 2013).

[12] See Exhibit 4 for summary statistics for the MPLS attendance zone, CCF neighborhood, and the rest of Cedar Falls.

[13] While the MPLS closure was officially approved by the Board of Regents on February 27, 2012, we use a cutoff date of April 1, 2012, representing a six-week period of time between contract date and the date of closing.

[14] Repeat sales include houses in Cedar Falls with two sales transactions between January 1, 2006 and July 31, 2013 at least six months apart (to avoid ''flips'').

[15] A Durbin-Watson test applied to our final model (see Exhibit 6) indicates that detrending based on the price indices in Exhibit 3 removed all significant serial correlation.

[16] Variograms are available from authors upon request.

[17] See Cressie (1993) for a more in-depth discussion of this technique.

[18] As the largest employer (with multiple locations) in the Cedar Valley, John Deere's financial performance over this time period may have contributed to the stability of the Cedar Falls housing market. Strong commodity prices between 2007 and 2013 led to record-setting John Deere earnings and stock prices (John Deere, 2012, 2013).

[19] The opinions expressed in this study are strictly those of the authors and are not those of the Black Hawk County Board of Supervisors.

[20] ArcGIS (Environmental Systems Research Institute, Inc.) was used in this study.

[21] The group ''Rest of Cedar Falls'' includes all house sales in Cedar Falls except those located in the MPLS attendance zone.

[22] Housing sales were matched with the most recent test score, which were assumed to be reported annually on August 1. Besides the closure of MPLS, attendance zones did not change in Cedar Falls between 2006 and 2013.

[23] Results are available from the authors upon request.

[24] To verify that our detrending method (see housing price indexes in Exhibit 3) sufficiently corrected for temporal (or serial) correlation, we applied a Durbin-Watson test on the full model residuals. The test indicated no significant temporal correlation.

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