RENEWING OUR CITIES

A Case Study on School Choice's Role in Urban Renewal

Bartley R. Danielsen, Ph.D.
David M. Harrison, Ph.D.
Jing Zhao, Ph.D.

EdCHOICE

ABOUT EDCHOICE

EdChoice is a nonprofit, nonpartisan organization dedicated to advancing full and unencumbered educational choice as the best pathway to successful lives and a stronger society. EdChoice believes that families, not bureaucrats, are best equipped to make K–12 schooling decisions for their children. The organization works at the state level to educate diverse audiences, train advocates and engage policymakers on the benefits of high-quality school choice programs. EdChoice is the intellectual legacy of Milton and Rose D. Friedman, who founded the organization in 1996 as the Friedman Foundation for Educational Choice.

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EXECUTIVE SUMMARY

Urban economic development resources are often focused on bringing jobs and affordable housing to downtown areas. In contrast, there has been very little consideration given to how public charter schools and other school choice programs might act as economic development catalysts.

This study examines relocation decisions made by families whose children are enrolled in a successful arts-intensive urban public charter school. We find that the school is a strong relocation attractor, and families gravitate toward the school after their children enroll. To the extent public charter schools and/or other parental-choice options influence family relocation decisions, continued growth in these programs may provide a useful policy tool informing urban design and revitalization initiatives in areas where economic growth is otherwise stunted by inferior assigned schools.

Taken in an appropriate context, the findings in this paper perhaps should be unsurprising. Each fall, millions of young men and women move away from their parent's homes and toward college campuses. While some universities actually require students to live on the campus, most do not. Living closer to campus simply improves a student's quality of life. Watching the annual migration to college towns one concludes that universities attract students and make large direct contributions to the economic vitality of surrounding communities.

Unlike colleges, conventional public-school systems assign students to schools based upon where the students live prior to enrollment. Families who can afford to live in a good school district move into the district, and then they enroll in the assigned school. Good assigned schools are a valuable amenity associated with relatively wealthy neighborhoods, but inferior assigned schools depress property values in communities assigned to them.

Public charter schools (and private K–12 schools) often separate the mandatory geographic linkage between where a family lives and where the family's children are allowed to attend school. In this regard, public charter schools and private schools are dissimilar from conventional public schools, and they are probably more like colleges in the way they impact their surrounding communities.

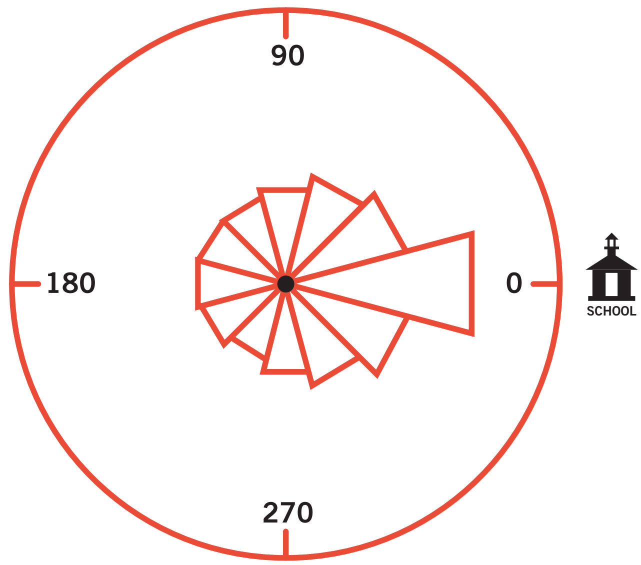
Background and Setting for the Investigation

This case study investigates the impact the Orange County School of the Arts (OCSA) has exerted on the relocation decisions of families whose children attend the school. The school was originally established in 1987 and operated out of Los Alamitos High School. In early 2000, the school was officially reorganized as a public charter school and relocated to Santa Ana, California. In 2000, Santa Ana was one of the least financially prosperous communities in the county, and it was widely regarded as having an underperforming public school system that was generally unattractive to families with children. Evidence of flight away from non-charter public schools in this community (or avoidance by families with school-age children who move to Orange County) is readily apparent. As compared to the whole of Orange County, 11 percent fewer elementary school-age children reside in Santa Ana than should be expected given the number of preschool children. This statistic is both the worst percentage in Orange County and one of the worst in southern California, and it provides meaningful insight into the perceived quality of non-charter public schools within the city.[i] Oddly, this economically depressed environment made the city relatively attractive to OCSA due to the relatively low rental rates available in vacant downtown space.[ii] Today, the school serves students in grades 7–12, and it has grown substantially to a Fall 2015 enrollment of

[i] An imbalance of school-age children vs. preschool children could exist for two reasons, which are not mutually exclusive.
[ii] The term "depressed" can take more than one meaning. An important measure in this context is that most of Santa Ana qualifies as low-income (less than 50 percent of the area median income) or moderate income (50 percent to 80 percent) for purposes of the federal Community Reinvestment Act.

nearly 2,000 students drawn from a wide geographic area. The school has an academically rigorous college-preparatory curriculum that is augmented by nearly three hours of advanced instruction per day in one of 15 arts conservatories.

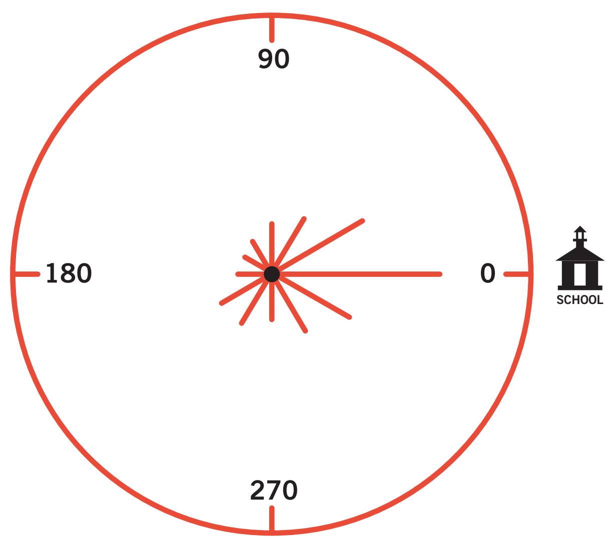
Proportion of Families Moving in Each Direction (relative to school located at zero degrees)



Study Methodology

In contrast to traditional public schools that draw students only from a prescribed catchment area, OCSA accepts students regardless of where they live; school district boundaries do not come into play. This is typical of charter schools across California, and it is the norm across much of the country as well. Because the school operates without a catchment zone, students and their families can relocate without being forced to withdraw from the school. To evaluate the impact of the school on family relocation decisions, we examined home residence data for 7,002 students who attended OCSA between the 2000–01 school year and the 2013–14 school year.

Average Move Distances by Direction

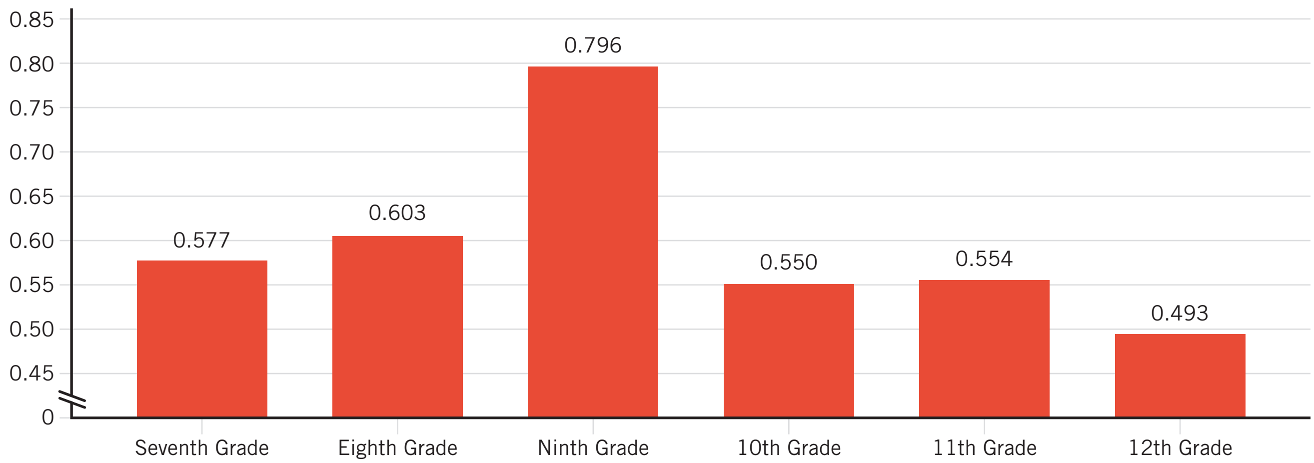


Note: Figure 5 depicts observed mean move distances for each of the bins shown in Figure 4.

Key Findings

- Families who live near the school (in Santa Ana, California) are substantially less likely to relocate than families who live farther away.
- 1,217 families moved during the period studied, and their moves were strongly biased toward the school.
    - o The top figure above presents a rose diagram showing family moves. The areas shown in each segment of the diagram are proportional to the number of students who have relocated in any particular direction, relative to their original address at the center of the diagram.

Concentration Parameter Estimates (*k*)



- o The fraction of relocating students who moved in a direction within 15 degrees of the school is shown by the largest wedge, in the top figure on the previous page which contains 21.4 percent of the observations.

- o For comparison purposes, if moves were not biased toward the school, only 8.3 percent of the moves would be observed in each wedge.

- The magnitude of the school's attractive power can be expressed by a statistical measure called the "concentration parameter." When there is no attraction exerted, the concentration parameter equals zero, and each wedge in the top figure on the previous page would be of equal size.

  - o The actual concentration parameter (κ) is 0.6184. This concentration is very similar to that previously found for workplace attractions.[iii]

- The bottom figure on the previous page shows that students who moved directly toward the school (± 15 degrees) moved, on average, more than five times as far as students who moved directly away from the school. This suggests that families are eager to move closer and reluctant to move away.

  - o The length of each line segment in the bottom figure on the previous page is proportional to the average move distance for each cohort.

- While students matriculate into the school in grades 7–12, the attraction seems to be particularly strong for families enrolling a child at the beginning of the ninth grade. The figure above shows the concentration parameter estimates for each enrollment grade.

- Since OCSA's establishment as a charter school in Santa Ana, the school has grown substantially, the area around the school has been revitalized, new businesses have opened nearby, and the local crime rate has fallen dramatically.[iv]

[iii]For the von Mises distribution of parent population when n is large and k = 0 the statistic $2n\overline{R}^2$ is approximately $\chi 2$ distributed with two degrees of freedom. In this test the value is 189.5. The p-value is < 0.00001.
[iv]Matt Coker (2011, December 20), Irvine and Santa Ana (Yes, That Santa Ana) are Dueling Safest Cities in America, *OC Weekly*, retrieved from http://www.ocweekly.com/news/irvine-and-santa-ana-yes-that-santa-ana-are-dueling-safest-cities-in-america-6470722.

Summary Assessment of Outcomes

Overall, the level of attraction exhibited by OCSA must be viewed as relatively high. There are almost 2,000 students and several hundred employees who commute to downtown Santa Ana on a daily basis. The city would certainly view attracting a firm with more than 2,000 employees as a positive development for the city. Since the school exhibits a family attraction level similar to that previously found for employers, this may be an appropriate comparison.

From an economic development perspective, it is worth noting that OCSA's arts focus may make it unusually attractive. During "after hours," OCSA students are engaged in more than 150 public performances and events each year. These performances draw students, families, and patrons back into the city where they also visit restaurants and other businesses. While it is likely that non-arts-based charter schools are also developmentally attractive, cities seeking to foster economic development might find arts-based charter schools (or charter schools with a heavy arts or other performance component) to be particularly impactful due to these after-hours spill-over effects in the community.

INTRODUCTION

The Orange County School of the Arts (OCSA) is a seventh–12th grade charter school located in downtown Santa Ana in Orange County, California. The school caters to middle- and high-school students with talents in the performing, visual, literary, and culinary arts with an educational program designed to prepare students for opportunities in both higher education and professions in the arts.

Before OCSA's establishment, Santa Ana was an unlikely location for a successful arts-based charter school. The city may fairly be characterized as a relatively poor, Hispanic city located in the middle of Orange County, a generally wealthier set of communities.[1] However, OCSA located in Santa Ana because it received early political support from the mayor and other local figures who expressed enthusiasm for arts-based education.[2] The school also received financial assistance from the state of California which viewed the school's relocation to Santa Ana as an appropriate "infrastructure project" designed to revitalize Santa Ana's underutilized downtown area. The political and financial support made locating OCSA in Santa Ana feasible.

OCSA's appeal to applicants is primarily due to the unique educational environment offered by an arts-focused school. A rigorous academic program runs from 8:05 a.m. until 2:10 p.m. each day. As evidence of the quality of these academic offerings, 99 percent of OCSA students continued their education in college in the 2009 graduating class. Artistically, from 2:15 p.m. until 4:50 p.m. each day, OCSA students are required to participate in one of 15 focused arts conservatories. These programs are offered across the institution's five major content areas as follows:

School of Applied Arts

- Culinary Arts and Hospitality

School of Dance

- Classical and Contemporary Dance
- Commercial Dance
- International Dance

School of Fine and Media Arts

- Creative Writing
- Digital Media
- Film and Television
- Integrated Arts
- Visual Arts

School of Music

- Classic Instrumental Music
- Classical Voice
- Contemporary Music

School of Theatre

- Acting
- Musical Theatre
- Production and Design

These conservatories offer aspiring artists an opportunity to refine their skills and flourish in a supportive artistic environment.

OCSA's campus is in many regards a model effort of urban redevelopment. Although "redevelopment" is a broad term, a reasonable reference source for common vernacular, Wikipedia, defines "redevelopment" as "any new construction on a site that has pre-existing uses." Variations on redevelopment include "adaptive reuse", which describes the conversion of older structures to new, more marketable uses. OCSA received financial assistance from the state of California to adaptively reuse and repurpose campus buildings as part of an infrastructure project specifically designed to revitalize Santa Ana's underutilized structures.

Accordingly, OCSA's campus is a near-model of adaptive reuse. The main classroom building and two other principal school buildings along Main Street were originally used as banks. Each still has its original vault, and these spaces are used as teacher work rooms. The vault in the main tower has also been used as an octagonal theatre. A fourth major campus building, Symphony Hall, was built in 1922 as a Christian Science church. The building has been converted to a performance space.

Against this backdrop, the underlying purpose of this study is to look beyond the buildings and to document the magnitude of the "community creating" power of OCSA. By extension we may be able to make inferences about the likely impacts of other arts-focused charter schools in revitalizing urban areas.[3] Urban redevelopment resources are frequently focused on bringing jobs and affordable housing to downtown areas. However, the Santa Ana experience suggests that arts-oriented schools may be even more powerful redevelopment tools.[4] In order to effectively make this case, however, metrics need to be developed and tested. Toward that end, the measure provided by Danielsen, Harrison, and Zhao is well-suited to this task, as it uses a statistically powerful test.[5] Using this tool, the research questions that are addressed in this study may be summarized as follows:

- Does the school attract families toward the school's location when they relocate? (a manifestation and driver of economic stimulus)
- If so, what is the magnitude of this attraction?

The answers to these questions are important both for attracting general funding and regulatory support for similar schools, as well as for informing urban redevelopment and design efforts.

LITERATURE REVIEW AND CONTRIBUTIONS OF THIS REPORT

Over the last several years, numerous papers have begun to document the effects of various school choice programs, such as charter schools and voucher programs, on surrounding communities. In particular, these studies have considered the potential impact of school choice programs on residential property values. While we briefly summarize this literature, we also refer the reader to Danielsen, Fairbanks, and Zhao for a more complete discussion of this topic.[6]

Charles Tiebout's seminal paper describing the effects of catchment-area-based school assignments led to an early understanding of how school assignments based on students' home addresses eventually separate wealthier families from poorer families. Relatively wealthy families then enjoy better-funded and more successful schools paid for by higher property taxes on higher-priced homes. These higher home values reinforce the equilibrium because poor families cannot afford to move into the neighborhoods with better schools.[7]

As observed in practice, Tiebout sorting is commonly referred to as people "voting with their feet." A series of theoretical and simulation-based papers by Thomas Nechyba and Maria Marta Ferreyra investigated how systems that allowed families to choose schools other than an assigned public school could break down this sorting equilibrium and create areas with greater economic diversity.[8] This insight led to numerous empirical papers which generally conclude that school choice programs raise relative property values in otherwise economically depressed areas.[9]

Two important concepts emerge from an analysis of these papers:

1. assigned schools lead to a separating equilibrium meaning the spatial segregation of communities on the basis of income, school quality, and property values,

2. school choice programs undermine this separating equilibrium by severing the link between place of residence and school assignment.

While these conclusions are important, they have limited application to an analysis of OCSA's impact on Santa Ana. The referenced studies examine how school choice systems alter property values, but they do not address how *an individual charter school* might change the surrounding urban space. While downtown Santa Ana has been revitalized, OCSA is not the only new institution. In fact they are not the only new charter school in the area. Two charter elementary schools opened on adjacent properties, and almost 3,400 children now attend school within two blocks of Main Street.[10] How might we assess OCSA's role in the revitalization?

For this task, we examine residential relocations for families who actually attend OCSA. Danielsen, Harrison, and Zhao examined residential relocation of families whose children attend a K–12 charter school in North Carolina.[11] They developed a statistical model that predicts where relocating families would be likely to move, and then use student mailing address changes to ascertain where they actually chose to relocate. They found that families are much more likely to relocate toward the school than would be expected if the school did not exert any attraction. These techniques are employed in the current study to measure the magnitude of family relocation attraction toward downtown Santa Ana.

Previewing our results, we find that OCSA exerts a strong and statistically robust attraction on students' families, and it exerts an unusually strong attraction on the families of children enrolling in the ninth grade. Overall, OCSA's attraction appears to be similar to that of businesses on employees. An interpretation of this result is that the families of almost 2,000 OCSA students are attracted toward Santa Ana at a rate that might be expected for an employer of similar size sited downtown.

DATA, HYPOTHESIS, AND DESCRIPTIVE INTERPRETATIONS

The data employed throughout this analysis are provided directly by OCSA and cover school years from 2000–01 to 2013–14. The data set includes students who have been admitted in the spring of each year for enrollment in the subsequent academic year that begins in the fall of the same calendar year. To ensure student anonymity, each observation record is identified only by student ID number. Other than the grade level and the address of record for each student, we do not have access to any other student specific information. For example, we do not know the name or gender of any student, and we have no information regarding the academic success of the student before, during, or after enrollment at the school.

Admission to the school is highly competitive. Approximately 2,000 students apply to the school each year, and only approximately 500 of these student applicants are accepted for admission. Students must first qualify academically to be considered. The current standard for admission is that the student's most recent (semester or trimester) report card must have no "F" grades and a minimum academic G.P.A. of 2.0 or better.

Once the student satisfies this minimum academic threshold, the student auditions for one (or more) of the school's conservatories. OCSA states "acceptance is primarily based upon the audition results."[12] While siblings may attend the school, unlike most charter schools, attendance by a sibling does not assure admission, or even preferential treatment, in the admission process.

The data we have collected identify 7,002 students for which we have at least one home address observation. The school's data on each student includes a single mailing address for each school year. We are also able to identify each student's address at the time of application.

After the student is admitted, we observe changes in mailing addresses annually in the data. All addresses are presumed to be the student's physical residence. However, for some of our tests, we presume reported addresses that are very far from the school cannot be actual "home" for the student during the school week. For example, if a student's listed address is in San Francisco, which is more than 400 miles away from Santa Ana, it is nearly impossible for that student to actually be residing in the reported address and attending OCSA. Rather, the student likely has a parent residing in San Francisco, while the student resides with another relative or friend during the week. In any event, to prevent these outliers from biasing our results, for many tests we exclude students whose address of record is more than 50 miles away from the school (1.6% of the observations). In some cases, this may improperly exclude students who applied to the school while living far away but have moved closer to the school after enrollment. Excluding these students probably leads us to underestimate the attraction exerted by the school.

We used ArcGIS Online from Esri to geocode both the location of each student's address, as well as the school's location. Table 1 presents summary statistics on the original linear distance between the school and the families whose children were admitted.

Although a few families applied to attend the school from distances that are more than 50 miles away, these students were almost certain to relocate closer to the school if they were admitted. Because including these students will likely bias the results, and to render reported results as less representative of other schools, we focus our attention on students who lived less than 50 miles from the school at the time of application. For these students, the

TABLE 1 Original Linear Distance in Miles from Home to School for Enrolled Students

Summary Statistics	Original Linear Distance
Mean	10.76
Std. Dev.	7.28
1st percentile	0.72
5th percentile	1.57
25th percentile	5.70
Median	9.35
75th percentile	14.74
95th percentile	24.94
99th percentile	35.38
Min	0.11
Max	49.80
N	6,893

FIGURE 1 Original Linear Distances for 25th, 50th, 75th, and 95th Percentiles

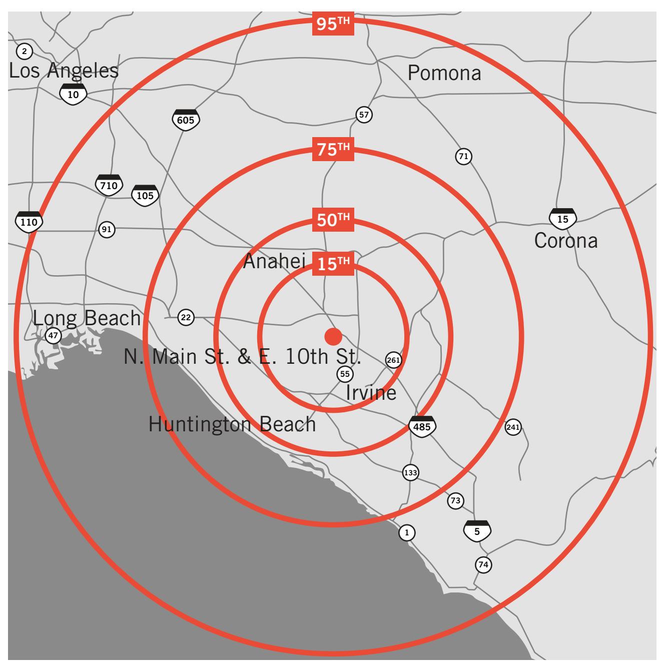


TABLE 2 Original Linear Distance in Miles by Admitted Grade

First Enrolled Grade	Original Linear Distance (in miles)							
	N	Mean	Std. Dev.	Min	Q25	Median	Q75	Max
7th (25% of total)	1,731	10.13	6.33	0.11	5.87	8.99	13.21	49.80
8th (17%)	1,187	10.47	7.02	0.22	5.62	9.24	14.75	47.93
9th (26%)	1,792	11.03	7.85	0.19	5.36	9.37	15.44	49.49
10th (14%)	983	10.82	7.56	0.11	5.28	9.17	14.84	49.25
11th (10%)	668	11.71	7.87	0.39	6.26	10.26	15.55	49.71
12th (8%)	532	11.27	7.33	0.24	6.32	10.08	14.91	47.49
Total	6,893	10.76	7.28	0.11	5.70	9.35	14.74	49.80

average initial commute (linear distance) is 10.76 miles with a median distance of 9.35 miles.[13] Three-quarters of the students originally lived within 14.74 miles of the school, and 95 percent lived fewer than 25 miles from the school. Figure 1 presents concentric circles for original distances at the 25th, 50th, 75th, and 95th percentiles.

Table 2 further refines this distance analysis and provides summary statistics for each admitted grade level. Notice that more than half of the students enroll in either the seventh or the ninth grade. Students enrolling in the seventh grade live, on average, slightly closer to the school initially. Students enrolling in grades 10–12 tend to live slightly farther away from the school when they first enroll.

Which Families Moved?

Comparing addresses at the time of application to subsequent mailing addresses, we find that 1,217 families (17.7 percent) changed addresses (i.e., moved) after they were admitted to the school. The remainder did not change addresses over our sample period. We assume that a change of mailing address constitutes a change of residence.

We use a probit analysis (see Appendix 1) to assess the factors that make a family more likely to move after enrolling a child in the school. Factors which we find to be important include the following:

- The child's grade level at enrollment: Families who enrolled a child into the school at a lower grade are more likely to move, probably because they have more time to do so before the student reaches graduation. They may also be more motivated to move because they have more years of expected school commuting.

- Whether the child remained enrolled until graduation: Children who remained in school until graduation were more likely to relocate simply because they have had a longer period of time in which to do so.

- Whether the child dropped out of OCSA: These students probably have not dropped out of formal education entirely, but they left OCSA prior to graduation. Students who left OCSA before graduation were less likely to have changed address prior to leaving the school. Many students in the sample have neither graduated nor dropped out because they continued to attend the school at the data collection date.

- Original distance from OCSA: Families with longer home-to-school commutes are more likely to move in order to reduce their commuting time and distance.

Did the Movers Move Closer? Some Non-Parametric Tests

We focus our attention next on the families in the sample that moved after their child was enrolled in the school. Let d_O be the distance between the family's original home and the school, and let d_N be the distance between the family's new home and the school. If $(d_O - d_N) > 0$, the family moved closer to the school. In fact, the average value of $(d_O - d_N)$ was 22.5 miles for the full sample of 1,217 families. However, this value is inflated by a few very long moves made by families who lived farther than 50 miles from the school initially. When we focus on the 1,140 "local movers" with an original commuting distance (and ending distance) of less than or equal to 50 miles from school, the average value of $(d_O - d_N)$ is 1.54 miles.

A "sign test" shows that 609 of these 1,140 local movers (53.4 percent) relocated closer to the school, while 531 moved further away (46.6 percent). If the true underlying probability of relocating closer, as opposed to further away, is 50 percent, the chance of observing 609 or more positive values of $(d_O - d_N)$ within this subset of local movers is only 1.13 percent.

In fact, because there is always more space farther away from the school than nearer to it, random moves that are not intentionally nearer the school (unbiased moves) would result in $(d_O - d_N) > 0$ much less than half of the time. For example, consider a group of persons who live in independent residences one mile from the school, but none of whom have any interest in the school. Random moves by this group will bring each one closer to the school only if they move into an area that is 3.14 (i.e. π) square miles, centered on the school. The area that is not closer to the school is vastly larger. Even if the group is constrained to moves within the state of California, the available area that is nearer to the school is less than 0.002 percent of the possible move area.

Thus, the proper benchmark would not be 50 percent for unbiased moves, but would be less than 50 percent and dependent upon d_O. The following section presents the methodology needed to adjust for d_O for each family.

A MODEL OF SCHOOL ATTRACTION

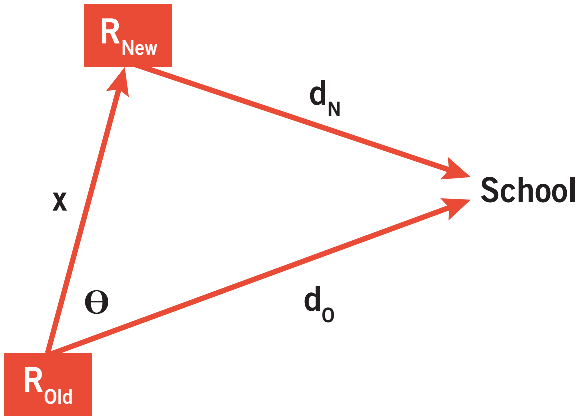
The foregoing analyses help describe the relationship between school location and home relocation choice. However, if we want to fully understand the magnitude of the school's attraction in residential relocation decisions, a two-dimensional spatial model of the relocation decision is useful. Ideally, the model will (1) provide testable hypotheses concerning the probability of moving closer to, or further from, the school and (2) provide testable hypotheses concerning the effect of pre-enrollment student commute distance. In an intuitive sense, these hypotheses might be described as follows:

1. Families are likely to move closer to the school after enrollment. (After all, university students seem to gravitate back to college towns each fall when classes begin.)

2. Families who live farther away from the school initially are more likely to be attracted toward the school than those who already live close by. (Again, some college students continue to live with parents at their original home address, if that address is nearby.)

For simplicity, we adopt the following description of the model. Consider a family's residential relocation as shown in Figure 2 on the following page.

FIGURE 2 Structure of School-Residence Relations

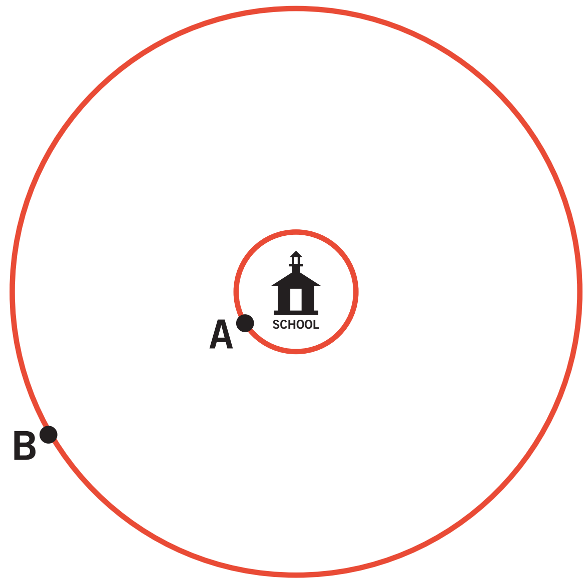


In the Figure 2 diagram, the student lives at the residence $\boldsymbol{R_{Old}}$ prior to enrolling in the school. The distance the student lives from the school is identified as $\boldsymbol{d_O}$. After being admitted to the school, the student moves to a new residence, designated as $\boldsymbol{R_{New}}$. The distance moved from $\boldsymbol{R_{Old}}$ to $\boldsymbol{R_{New}}$ is designated as vector X. After moving to $\boldsymbol{R_{New}}$, the new commuting distance to the school is designated by the vector $\boldsymbol{d_N}$. Summarizing the distances involved in this move, the student moved X miles from $\boldsymbol{R_{Old}}$ to $\boldsymbol{R_{New}}$, and the commute distance to the school changed from $\boldsymbol{d_O}$ to $\boldsymbol{d_N}$.[14]

An intuitively simple but flawed method of analyzing whether the school is an attractor would be to test whether more families move closer to the school than away from the school. This would presume a binomial probability with $\boldsymbol{Pr(d_O - d_N > 0) = 0.5}$. In fact, if we apply a sign test, 669 of the 1,217 movers moved closer to the school, and 548 moved away from the school, and we will reject the hypothesis with a **p-value** of **p=0.0003**. Similarly, the Wilcoxon sign-rank test rejects the null **(H_0: mean=0)** with a one-tailed p-value less than 0.0001.[15]

However, the presumption that the probability is described by a binomial distribution is obviously flawed. To illustrate this point, consider two childless individuals in Figure 3, neither of whom has any interest in, nor affiliation with, the school shown at the middle of the figure.

FIGURE 3 Distance to School and Move Probability for Two Individuals



If Individual A moves, she is highly unlikely to move closer to the school because the area inside the small circle represents a small fraction of the total potential move locations. Individual B has a higher probability than A of moving closer to the school simply because there are more addresses inside the larger circle that satisfy the condition $\boldsymbol{d_N < d_O}$. Even for Individual B, $\boldsymbol{Pr(d_O - d_N > 0) = 0.5}$ is only asymptotically true. For example, if an uninterested party lives 1,000 miles due east of the school, then approximately half of the possible relocation moves would take him slightly west of his starting location, and approximately half the moves would take him east. Only for very large values of $\boldsymbol{d_O}$ could $\boldsymbol{Pr(d_O - d_N > 0) = 0.5}$ be approximately appropriate.

We cannot determine how attractive the school really is unless we can establish a benchmark of how many families could be expected to move closer (inside their unique circle) purely by chance. This probability is dependent upon $\boldsymbol{d_O}$ (the size of the circle), **X** (the distance moved) and **θ** (the direction of the move.)

Theta **(θ)** is the angle formed by moving from vector to vector **X**. For movements in a counter-clockwise direction from the original school bearing (such as

FIGURE 4 Proportion of Families Moving in Each Direction(relative to school located at zero degrees)

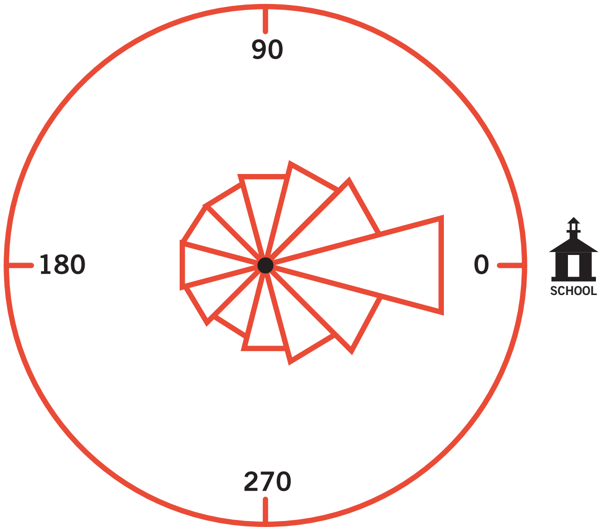
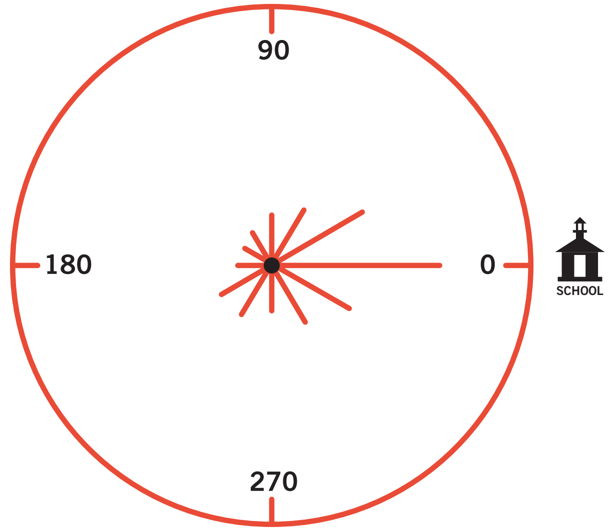


FIGURE 5 Average Move Distances by Direction



Note: Figure 5 depicts observed mean move distances for each of the bins shown in Figure 4.

the move shown in Figure 2), the value of theta is negative. For movements in a clockwise direction, the value of theta is positive. If a family moved directly toward the school, the value of theta would be zero. For a family moving directly away from the school, the value of $\boldsymbol{\theta}$ is $\boldsymbol{\pi}$ (or $\boldsymbol{-\pi}$, which has the same meaning). Mathematically, no move can ever end up closer to the school if theta is greater than $\boldsymbol{\pi/2}$ or less than $\boldsymbol{-\pi/2}$, but even moves in the appropriate direction can end up farther from the school if the move distance **X** is too large.

Visual Depictions of the Data

To help the reader visualize the move pattern of relocating families, in Figure 4 we have grouped families who moved in a particular direction, relative to the school, into 12 30-degree directional bins. Every family is assigned to a single bin. For the observations contained in each bin, we calculate the fraction of the total movers contained in the bin. We also calculate the average move distance for each subgroup. Move distances are visually depicted in Figure 5.

Figure 4 shows a rose diagram based on the fraction of movers who moved in any particular direction. The area in each wedge is proportional to the number of students who moved in a particular direction, relative to the school. The largest wedge, showing students with moves within 15 degrees of the school contains 21.2 percent of the moves. The smallest wedge contains only 4.2 percent. The three wedges which comprise the fourth of the circle closest to the school contain 43.8 percent of the moves. In this context, the magnitude of the family relocation bias seems obvious.

The mean move distances are graphically depicted in Figure 5. The mean distance moved toward the school is 16.98 miles, while the mean distance moved directly away from the school is only 3.21 miles.

The exact values in these images are shown in Table 3. The group names in the legend reflect the geographic bounds on each bin. The first group is for moves in the direction of the school, which includes moves between **+15º** to **-15º** (i.e. **+345 degrees**). This group is labeled as "group <15 & >345". The bins in the table are listed in a counterclockwise direction from the school.

Despite the strong bias in direction and distance exhibited in the family moves, we should

TABLE 3 Proportion of Movers and Mean Move Distances, by 30-Degree Bin

Group	Percent of Total	Mean value of X
<15 & >345	21.2	16.98
15-45	11.0	10.39
45-75	8.6	6.18
75-105	7.0	4.58
105-135	5.5	3.48
135-165	5.9	2.77
165-195	5.3	3.21
195-225	5.3	5.33
225-255	4.2	5.84
255-285	6.0	4.58
285-315	8.3	6.97
315-345	11.6	8.89

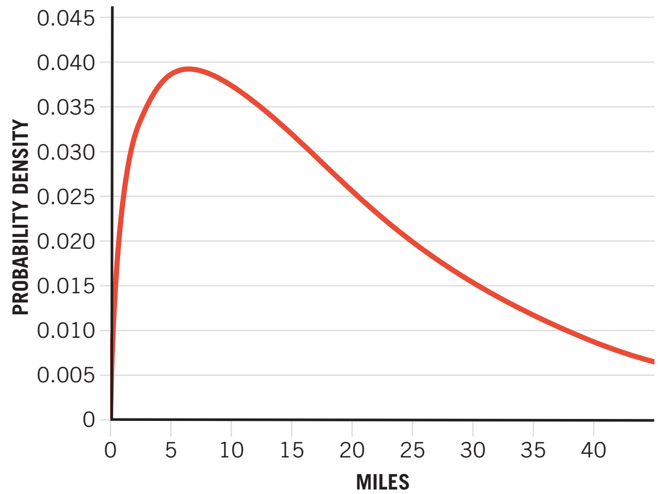
acknowledge that some students may apply to OCSA because their families expect to move to Santa Ana anyway. At least three possible relationships could exist between a family's decision to apply to the school and the family's relocation decision.

1. Parents may desire to have their child attend the school, and once their child is admitted, they choose to move closer to the school to reduce their child's commute distance;

2. Some parents might have been planning to move closer to Santa Ana regardless of admission to the school but apply to the school because it will be convenient once the family moves; and

3. Some parents are not attracted to the school but are to the area, and they are only willing to move once their child's school issue is resolved.

FIGURE 6 Distribution of Move Distances



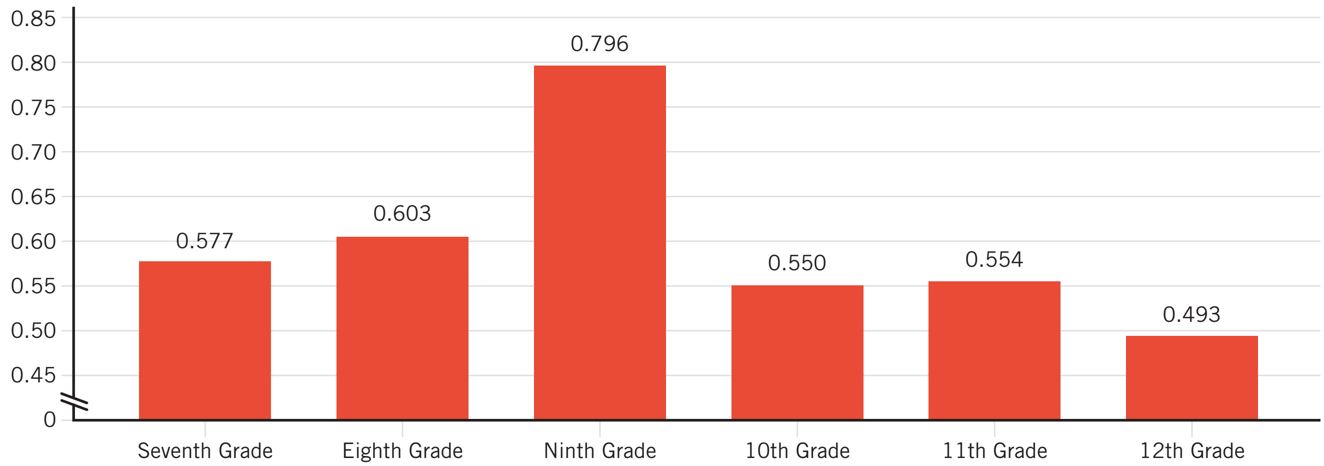
The methods of analyses used in this paper cannot distinguish between these possibilities. Likewise, these methods could not econometrically assign causality for college students' August relocations, although most people would suspect that causality predominantly runs from college enrollment to freshman residence relocation.

Statistical Descriptions of Moving-Family Data

This brings us to a formal model of the relationship conceptualized in Figure 2. The technical details of the model development are provided in Appendix 2, but fundamentally, a gamma distribution as shown in Figure 6 is used to model the move distances. The most frequent move distance (modal value) is approximately 5.8 miles.

The von Mises distribution is used to describe move directions.[16] This distribution takes the form of a normal distribution that has been wrapped around a circle. Accordingly, the parameters of the von Mises distribution are μ and κ, where μ is analogous to the mean of the normal distribution and κ is analogous to $1/\sigma$, where σ is the standard deviation from the normal distribution.

FIGURE 7 Concentration Parameter Estimates (k)



For the sample of relocating families in this study, **μ** is assumed to be 0 degrees, and the average move direction is consistent with this assumption. From the data, the concentration parameter **k** is estimated to be **0.6184**. (Procedures for estimating the parameters of the von Mises distribution are shown in Appendix 3.)

As a point of reference, both Clark and Burt and Clark et al. studied workplace attraction and found concentration parameter estimates of **k=0.638** and **k=0.668**.[17] Thus, OCSA's attraction **(k=0.6184)** is very similar to previously reported workplace attraction measures. However, Clark et al. report that only approximately 8 percent of their observed sample changed residence, while 17.3 percent of the families attending this school changed residence subsequent to their child's acceptance into the school.[18] Therefore, while the magnitude of the attraction is similar for those who moved, the propensity to move appears to be stronger in the school sample.

Figure 8 later depicts von Mises distributions for subsets of the data, and the relative magnitude of the move concentration for **k=0.6184** can be visualized to lie between **k=0.567** and k=**0.796** in the figure.

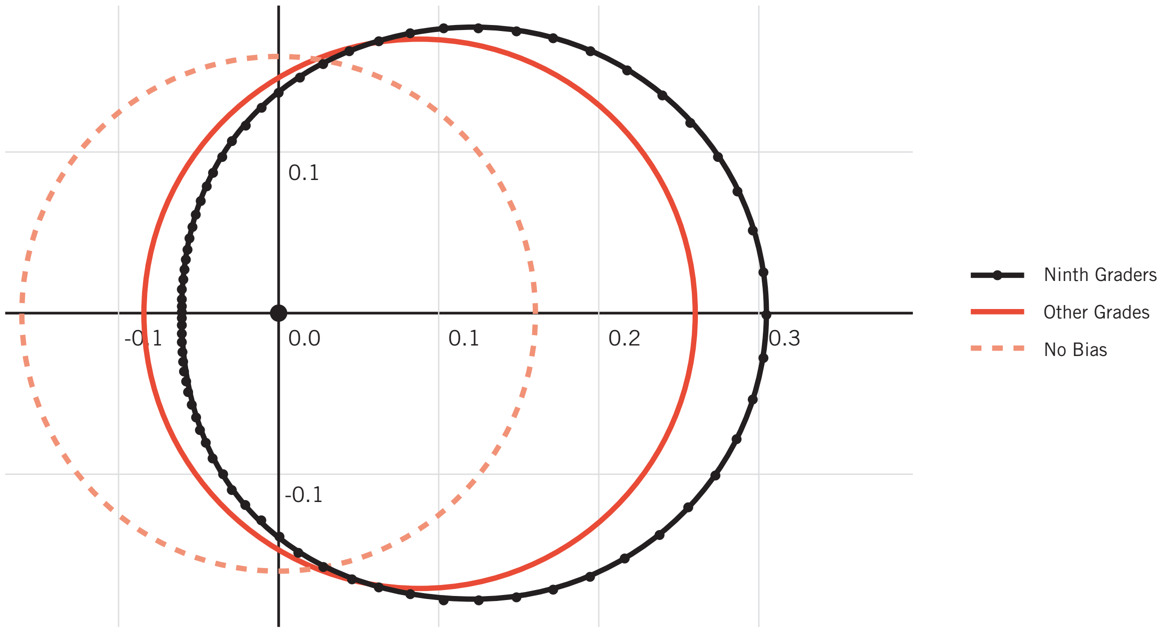
Grade-by-Grade Analysis

Because students enroll in the school for the first time at various ages (grades), we also expect the grade when the child first enrolled in OCSA to exert some influence over the level of attraction demonstrated by the school. For example, if a family enrolls their child for the first time in the 12th grade, we might expect the school's attraction to be relatively low since the child will only attend one year of classes at the institution before graduating. In contrast, there may be a strong school attraction for the families of seventh graders, simply because the child may attend the school for the next six years. To examine the influence of the child's grade of matriculation into the school on family relocation decisions, we calculate concentration parameters **κ** for students grouped by the grade of matriculation. These values are shown in Figure 7.

We find that the concentration parameter for students entering the ninth grade is significantly higher than for any other grade. The ninth graders' **κ** value is **0.796**, and the **κ** values for all other grades range from **0.496** to **0.603**. The overall **κ** value for non-ninth graders is **0.567**.[19]

It is not clear why a child who has enrolled in the school in the seventh or eighth grade would be less attracted toward the school, *conditional on moving,*

FIGURE 8 Elliptical Density Functions for Ninth Graders and Non-Ninth Graders



than one who enrolls in the ninth grade. Although families who have children approaching a gateway grade (kindergarten, middle school, and high school) may be more likely to move at that time, the **κ** value does not reflect a propensity to move. It reflects, conditional on moving, a propensity to move in the direction of the school.

In order to better visualize the level of the move direction bias that these **κ** values represent, in Figure 8 we present von Mises density functions for various **κ** values. These curves are continuous versions of the rose diagram shown in Figure 4. As a baseline, the density for **κ=0** (meaning an assumption of no attraction) is also shown. The density function for this baseline case is represented by a circle focused on the origin **(0, 0)**. The other two ellipses also have their focus at the origin, but they become more elongated as the value for **k** increases.

The reader should not be confused by the area of each ellipse. In each case the average distance to and from the focus to all points on the ellipse is the same. As the bias increases, holding the average distance from the focus constant automatically increase the area in the ellipse.

While the differing areas for the three ellipses are unimportant, what does matter is the variation around the origin. Notice that the moves by ninth graders are substantially more biased toward the school (located at the right).

Probabilities of Moving Closer Given Differing d_0 Values

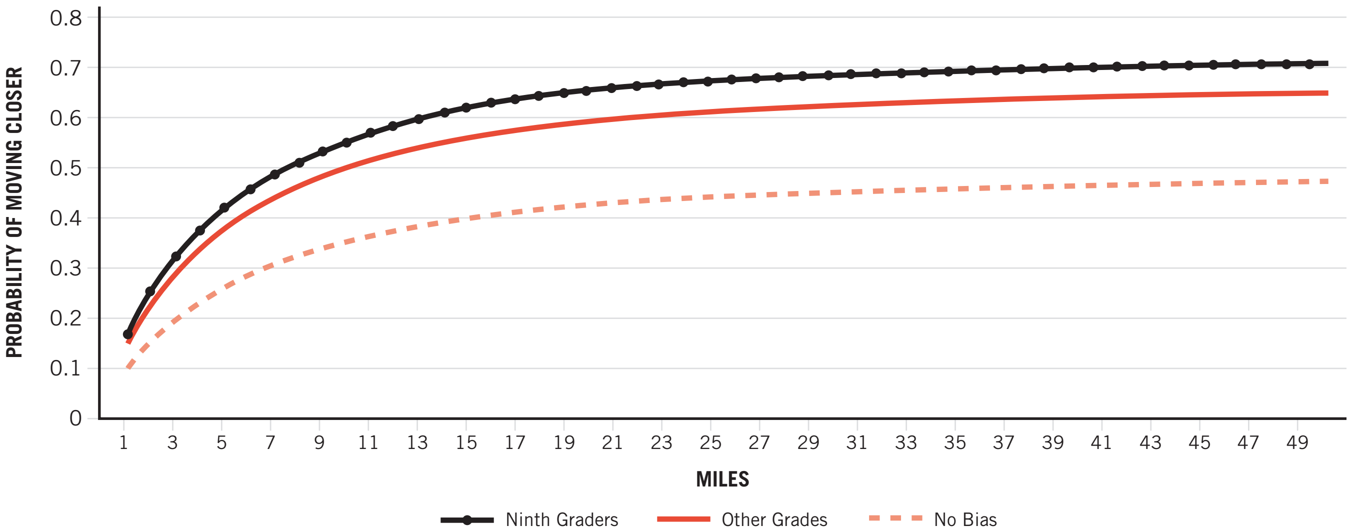
We estimate the probability that a family will move closer to the school using equation 7 from Appendix 2.

$$P(d_N < d_O) = \frac{\alpha^{\varphi}}{\pi I_O(k)\Gamma(\varphi)} \int_0^1 \frac{1}{\sqrt{1-t^2}} e^{kt} \int^{2d_0 t} x^{\varphi-1} e^{-\alpha x} dx dt$$

This is solved for various values of **k** and using numerical integration. Thus, we can establish the relation between how long a child's original commute to school is, and the probability that the family will move closer.

We solve for the above equation first under the assumption that the school exerts no attraction on the family. This is the baseline against which we measure the impact of the school's attraction level.

FIGURE 9 Imputed Probabilities of Moving Closer by Concentration Parameter



Given the observed attraction exerted by the school, we then assess the probability that a family will move closer. Figure 9 provides a visual depiction of $\mathbf{P}(d_N < d_O)$ for original commutes between 1 mile and 50 miles. The baseline assumption is **(κ=0)**. The data dictates an assumption for ninth graders of **(κ=0.796)** and an assumption for other students of **(κ=0.567)**.

Using data shown in Figure 9, we find that depending upon the initial distance from the school, non-ninth graders are 37 percent to 43 percent more likely to move closer to the school than would be expected by random chance (the baseline). Ninth graders are 50 percent to 59 percent more likely to move closer.

While it may be surprising that the increased probability is not greater for students living 50 miles from the school, we must recognize two factors that drive this result. First, the baseline probability of moving closer for a family living 50 miles from the school is already high. Notice in Figure 9 that it is asymptotically approaching a 50 percent probability. Second, values are based on imputed probabilities derived from the model parameters. These parameters are derived from the available data. As seen in Table 1, more than 95 percent of the observations reflect values for d_O of less than 25 miles.

d_O	Non-Ninth Graders $\dfrac{P(d_N < d_O)\mid\kappa = 0.567}{P(d_N < d_O)\mid\kappa = 0}$	Ninth Graders $\dfrac{P(d_N < d_O)\mid\kappa = 0.796}{P(d_N < d_O)\mid\kappa = 0}$
1 mile	1.43	1.59
10 miles	1.41	1.56
25 miles	1.38	1.52
50 miles	1.37	1.50

CONCLUSION AND COMMENTS ON FACTORS THAT MIGHT LEAD TO STRONGER/WEAKER ATTRACTIONS

This study examines the impact the OCSA has exerted on the relocation decisions of families whose children attend the school. The school draws students from a relatively wide geographic area, and it exerts an attractive power on enrolled families that is similar to that found for adult workplaces. Families who live near the school (in Santa Ana, California) are substantially less likely to relocate than families who live farther away. Hundreds of families (669) have moved closer to Santa Ana after enrolling a child in the school, and a substantial fraction (97 families; 14.5 percent) of these moved from a non-Santa Ana address into the city. While students may matriculate into the school in any grade from seventh through 12th, the school's relocation attraction power seems to be particularly strong for families enrolling a child at the beginning of the ninth grade.[20]

We also find that the school's attractive power is of the same general magnitude as workplaces previously examined. The school has almost 2,000 students currently enrolled, and it may be reasonable to consider its relocation impact as similar to that of a work place with a similar number of employees. However, because this is a case study of a single school, we should be careful to consider what factors may be unique to this school, and which are likely to be generalizable. Thus, we should consider factors that may strengthen or weaken OCSA's impact as an urban redevelopment catalyst.

Although the attraction by OCSA should be viewed as relatively large, there are several factors that might reduce OCSA's level of attraction. First, families are likely to consider the length of time that a student will be enrolled in the school when making a relocation decision. Thus, a K–12 school is likely to be more attractive than a differently configured school such as a grade 7–12 school. OCSA does not enroll students in elementary school. Thus, no student can expect to be enrolled for more than six years. A longer expected enrollment period would increase the benefits of moving closer to school because the family would be able to enjoy the commuting advantages over a longer period of time.

Second, although many charter schools give preference to siblings in admissions, OCSA provides no enrollment preference for siblings. All OCSA students are evaluated based upon artistic talent before being admitted. If siblings are not enrolled in OCSA, the family must consider the schooling options of their other children. In particular, for elementary-school siblings the Santa Ana options may not be desirable. As a result, multi-student families are probably less likely to apply to OCSA, and they are probably less likely to relocate near the school, at least until all children are successfully enrolled.

A third factor that may affect a school's attraction is the perceived financial stability of the institution itself. OCSA's viability was not always assured. Over time it has developed an excellent reputation, and it currently turns away many applicants. The school is now likely viewed as a relatively low-risk opportunity by families, but this may not have been true initially. We have not examined whether the attractive power of the school has increased over time, but this is a potential area for later study.

Fourth, OCSA has very specialized and focused extracurricular programs. Some families may be unsure whether those programs will prove to be acceptable to their children. In fact, some students find that OCSA's demanding programs are "too much of a good thing." The probit analysis in this study shows that families of students who dropped out of OCSA were less likely to have moved closer to the school prior to dropping out. It is unclear whether OCSA's attrition rate is higher than other charter schools, but attrition will always negatively affect family attraction. OCSA is a very successful school, and many families who remain enrolled probably see themselves as privileged to be there. Simply opening a school for the arts of unknown quality in a depressed neighborhood does not suggest a higher propensity to attract families will result. On the other hand, unlike a weak non-charter public school, a weak public charter school is unlikely to drive out families since no students will be assigned to it. Instead, the weak public charter school would be likely to fail and close.

A fifth consideration that might reduce the school's attraction is also related to the potential risk that a family might later wish to leave the school: the relatively unappealing traditional public school system in Santa Ana. If a student later decides to leave OCSA, the family might regret moving into the Santa Ana Unified School District. Maintaining a residence outside of Santa Ana can improve the default option for students who are not completely committed to remaining enrolled at OCSA.

One factor that may increase OCSA's attractive power is related to depth and breadth of the school's "after-school" activities. In fact, OCSA's primary reason for existing is its extra-curricular arts emphasis. Every student stays after school to engage in the arts. No one leaves campus when core classes end, and many students later return for evening performances—either as participants or as patrons supporting their friends' artistic endeavors. Given limited time and the depth of commitment required of OCSA students, long commutes are probably particularly unappealing. Thus, OCSA's deep arts-based focus may make the school particularly attractive in a family relocation sense.

Overall, despite multiple attributes that may mitigate against families being attracted toward the school, OCSA families appear to be attracted at a level that is similar to that observed in employees, relative to their work locations. Almost 2,000 students attend OCSA, and more than 200 employees work there. The city would certainly view attracting a 2,200-employee firm downtown as a very positive development for the city. Given that the school exhibits a family attraction level similar to that previously found for employers, this may be an appropriate analogy.

APPENDIX 1

Probit Analysis of Move Likelihoods

Comparing addresses at the time of application to subsequent mailing addresses, we find that 1,217 of the families changed addresses (i.e., moved) after they were admitted to the school. The remainder did not change addresses over our sample period. We assume that a change of mailing address constitutes a change of residence.

Assuming families make relocation decisions (in part) on the basis of the child's grade at enrollment, we expect families whose children were admitted at a lower grade, and hence expect a longer relationship with the school, would be more likely to relocate. To test this hypothesis, we specify the following probit model:

$$\begin{aligned} P(Moved_i = 1 | x_i) &= \Phi(x_i \beta) \\ &= \Phi(\beta_0 + \beta_1\, Admitted\ Grade_i + \beta_2\, Graduated_i + \beta_3\, Dropped_i + \beta_4\, Distance_i) \end{aligned} \quad (1)$$

Under this model specification, the marginal effects are given by:

$$\frac{\partial}{\partial t_j} P(Moved_i = 1 | x_i = t) = \frac{\partial}{\partial t_j} \Phi(t\beta) = \varphi(t\beta)\beta_j \quad (2)$$

where $\Phi(\ )$ is the cumulative standard normal distribution function and $\varphi(\ )$ is standard normal density. $Moved_i = 1$ indicates that family i moved after admission, while $Moved_i = 0$ indicates the family did not move. ***Admitted Grade****$_i$* is the grade at enrollment. We posit that families who enrolled a child into the school at a lower grade are more likely to move, in part because they have more time to do so before the student reaches graduation. They may also be more motivated to move because they have more years of expected school commuting. If younger children are more likely to move, β_1 will be negative. We also include several control variables in the regressions that likely affect each family's decision to relocate.

For example, $Graduated_i$ is a dummy variable equal to one if the student has graduated from the school, and zero otherwise. In contrast, $Dropped_i$ is a dummy variable equal to one if the student has dropped out of the school during our sample period, and zero otherwise. Everything else equal, we expect families to be more likely to move if their children graduated from the school, and less likely to move if their children dropped out of school. Thus, the coefficient estimate of β_2 should be positive, and the corresponding estimate of β_3 should be negative. $Distance_i$ is the pre-move linear distance from the school. All else constant, we also expect families with longer home-to-school commutes to be more likely to move in order to reduce their commuting time and distance. Thus, we expect the coefficient estimate of β_4 to be positive. Finally, we also control for the fixed effects of the calendar year at the time of enrollment.

Table 1.1 presents the results of the hypothesized model with variations. Below the partial effect of each independent variable, z-values are reported in parentheses. Elasticities with respect to each independent variable are also calculated with z-statistics shown underneath. Both the partial effects and elasticities are measured with respect to the mean value.

Table 1.1 shows results from the full sample, but restricting the analysis to children who originally lived within 50 miles of the school yields almost identical results. In the first specification, the only independent variable considered is Admitted Grade. The coefficient is negative and statistically significant, suggesting

TABLE 1.1 Probit Regressions Predicting the Probability of Moving

Dep. Var. = Moved (1/0)	Model (1)		Model (2)		Model (3)	
	Marginal Effect [dy/dx]	Elasticity [d(lny)/d(lnx)]	Marginal Effect [dy/dx]	Elasticity [d(lny)/d(lnx)]	Marginal Effect [dy/dx]	Elasticity [d(lny)/d(lnx)]
Admitted Grade	-0.0204*** (-6.91)	-0.9506*** (-6.85)	-0.0267*** (-8.57)	-1.2832*** (-8.47)	-0.0286*** (-9.17)	-1.391*** (-9.06)
Graduated			0.0343* (1.72)	0.0900* (1.72)	0.0304 (1.53)	0.0808 (1.53)
Dropped			-0.0876*** (-4.87)	-0.1900*** (-4.85)	-0.0934*** (-5.21)	-0.2059*** (-5.19)
Distance					0.0003*** (5.63)	0.0374*** (5.63)
Admitted Year Fixed Effects	Yes		Yes		Yes	
Log Pseudo Likelihood	-3172.0354		-3100.1655		-3057.5956	
Pseudo R^2	0.0171		0.0394		0.0526	
Predicted Prob.	0.1701		0.1644		0.1627	
Observations	6,967		6,967		6,967	

Notes: This table reports marginal effects and elasticities from probit regressions predicting the probability of moving. The dependent variable (*Moved*) is a binary variable that equals one if the family moves, and zero otherwise. The independent variables include original grade (*Admitted Grade*), an indicator variable whether the student graduated (*Graduated* = 1/0), an indicator variable for whether the student dropped out (*Dropped* = 1/0), the original commute distance in miles (*Distance*), and fixed effects for the calendar year in which the student was originally admitted (omitted from the table). Each specification builds on the previous one. The partial derivatives and elasticities of the dependent variable with respect to the independent variables are evaluated at the mean for each independent variable. Robust z-statistics are reported in parentheses. ***, **, and * denote statistical significance at the 1 percent, 5 percent, and 10 percent levels, respectively, in a two-tailed test.

that the lower the grade at enrollment, the more likely the student's family would move. The second specification incorporates indicator variables for whether the student graduated or dropped over our sample period. As expected, for students who actually graduated, their families were more likely to move after the students were enrolled **(β_2>0)**. We note that the coefficient β_2 is only significant at a 10 percent level. This is likely driven, at least in part, by the fact that there are students in our sample who were still enrolled at the end of our sample period, but will likely graduate at a later point in time. In comparison, for students who have dropped out of school, their families were less likely to have moved while the child attended OCSA. The coefficient estimate of β_3 is negative and highly significant.

The third specification incorporates the original linear distance between the family and school for enrolled students. The negative partial effect on Admitted Grade indicates that the lower the student's academic grade level at the time of admission, the more likely the family was to relocate. This finding is consistent with families choosing to relocate when they expect their children will be enrolled at the school for a longer period of time. For families that expect to be affiliated with the school for many years, the relative benefits of moving increase. The distance the family originally commuted to the school is also positively correlated with move probabilities.

APPENDIX 2
Modelling Move Distances and Directions

Multiple studies[i] consider relocations as a function of move distances from workplaces (analogous to this study of moves related to school location). Unlike those studies, which model move distances using an exponential distribution, we adopt the gamma distribution used by Danielsen, Harrison, and Zhou.[ii] This is a more general model that allows the data to select an exponential distribution if that provides the best fit.

$$g\,(X;\varphi\,,\alpha)=\frac{\alpha^{\varphi}}{\Gamma(\varphi)}X^{\varphi\text{-}1}e^{\text{-}\alpha X},\qquad X>0\text{ and }\varphi,\alpha>0. \quad (1)$$

This gamma distribution is parameterized in terms of a shape parameter **φ**, as well as the rate parameter **α**. The function **Γ(φ)** is defined to satisfy **Γ(φ) = (φ − 1)!** for all positive integers **φ**, and to smoothly interpolate the factorial between integers.

A second assumption of our model is that the move directions for students follow a von Mises distribution, as described by Gaile and Burt.[iii] The von Mises distribution is also known as the circular normal distribution. Accordingly, it can be viewed as an analogue to the normal distribution that is useful for analyzing two-dimensional data. The parameters of the von Mises distribution are **μ** and **κ**, which are analogous to the normal distribution's **μ** and **σ²**. Actually, **κ** is analogous to the inverse of **σ²**, **(1/ σ²)**.

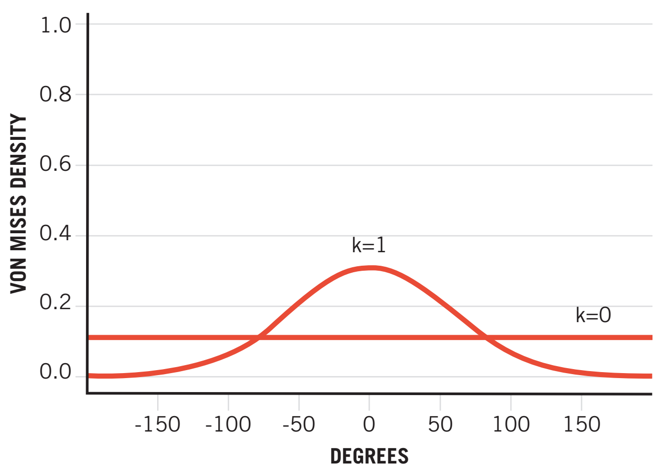
The assumption that student movements are, on average, in the direction of the school is captured as **μ=0** (an assumption that we test). For **μ=0**, the density function is defined as:

$$v\,(\Theta)=\frac{1}{2\pi I_0(k)}e^{k\cos(\Theta)},\qquad -\pi<\Theta<\pi,\ k\geq 0 \quad (2)$$

where **Θ** is the move direction described in Figure 2, measured in radians. I0 is a modified Bessel function of the first kind and order zero.

Figure 2.1 clarifies why the von Mises distribution is also described as the circular-normal distribution. Notice that for **k=1**, a graph of the density function looks very similar to a normal distribution. |However, unlike the normal distribution, the horizontal axis in Figure 10 does not extend from **-∞** to **∞**. Instead, the axis extends from **-180°** to **+180°**. Of course, these two values represent the same point on the circle, so the horizontal axis actually wraps around the circle. For larger values of **k**, the concentration at the origin increases and the standard deviation decreases. For **k = 0**, which also is depicted in the figure, the distribution becomes a circular uniform distribution.

FIGURE 2.1 The Density Function of the von Mises Distribution



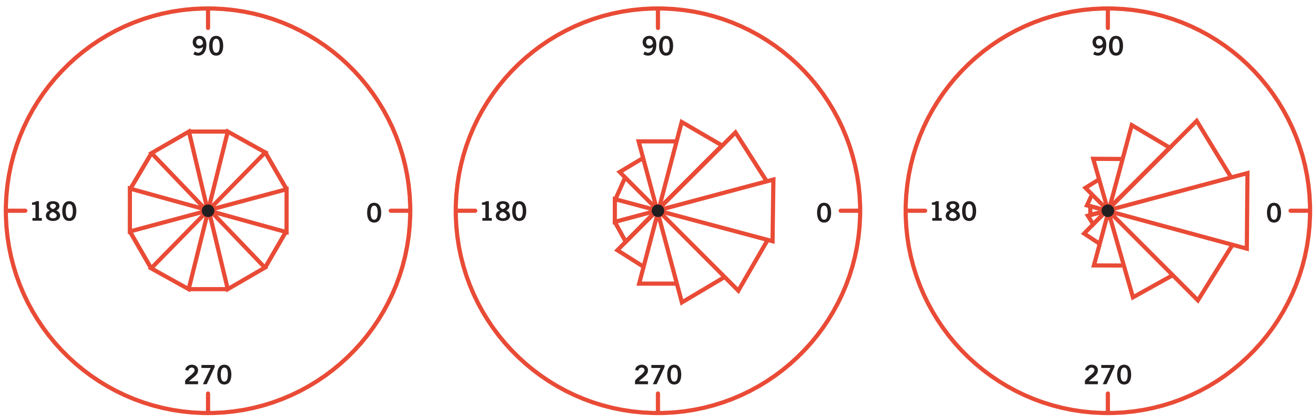
[i] John Quiqley and Daniel Weinberg (1977) Intraurban Residential Mobility: A Review and Synthesis, *International Regional Science Review,* 1, pp. 41-66, retrieved from http://journals.sagepub.com/doi/abs/10.1177/016001767700200104; William A. V. Clark and James E. Burt (1980), The Impact of Workplace on Residential Relocation, *Annals of the Association of American Geographers, 70*(1), pp. 59-67, ; Does Commuting Distance Matter? Commuting Tolerance and Residential Change, *Regional Science and Urban Economics,* 33, pp. 199-221, http://www.jstor.org/stable/2562825.

[ii] Bartley R. Danielsen, David M. Harrison, and Jing Zhao (2014), It Makes a Village: Residential Relocation After Charter School Admission, *Real Estate Economics, 42,* pp. 1008-1041, http://dx.doi.org/10.1111/1540-6229.12074 .

[iii] Gary L. Gaile and James E. Burt (1975), *Directional Statistics* [Monograph], retrieved from http://alexsingleton.files.wordpress.com/2014/09/25-directional-statistics.pdf.

Figure 11 presents a series of rose diagrams, which allow the reader to visualize the concentration of movement toward **μ=0** for various values of **k**. Each rose diagram is generated from a theoretical von Mises distribution with alternative values of the concentration parameter **k**. The area of each triangle is proportional to the number of moves in a particular direction, relative to the school's location. For **k=0**, the move directions are uniform, but for **k=2**, the moves are strongly concentrated toward **μ=0** (i.e., the direction of the school).

FIGURE 2.2 Rose Diagrams of Movement Concentration Toward μ=0 for Various Values of *k*



k=0 *k*=1 *k*=2

In combining move directions and distances, we assume that the move directions and distances are independent of one another. This assumption aids tractability, but biases against finding confirming empirical support if the assumption is invalid. Thus, as noted by Clark et al., "if the fit between observed and expected is good, we are confident of the results of the model."[iv] Accordingly, the joint probability distribution of movement distance and direction is described by:

$$c(X,\Theta) = g(X)v(\Theta) \quad (3)$$

Given these assumptions we develop a model of the likelihood that a student will move into a particular area defined by two distances **(X_1 and X_2)** and two angles **(Θ_1 and Θ_2)**,

$$P(X_1 < X < X_2,\ \Theta_1 < \Theta < \Theta_2) = \iint_{X_1\Theta_1}^{X_2\Theta_2} c(X,\Theta)d\Theta\, dX$$

where,

$$c(X,\Theta) = g(X)v(\Theta) = \left(\frac{\alpha^{\varphi}}{\Gamma(\varphi)}X^{\varphi-1}e^{-\alpha X}\right)\left(\frac{1}{2\pi I_0(k)}e^{k\cos(\Theta)}\right). \quad (4)$$

Recall from Figure 2 that students move closer to the school when $d_N < d_O$. Thus, we are specifically interested in the region where $d_N < d_O$. Specifically, we wish to solve for **P(**$d_N < d_O$**)**. From the law of cosines:

$$(d_N)^2 = (d_O)^2 + (X)^2 - 2(d_O X)\cos\Theta. \quad (5)$$

[iv] William A.V. Clark, Youngquin Huang, and Suzanne Withers (2003), Does Commuting Distance Matter? Commuting Tolerance and Residential Change, *Regional Science and Urban Economics, 33*, p. 212, http://dx.doi.org/10.1016/S0166-0462(02)00012-1.

APPENDIX 2
Continued

Thus,

$$P(d_N < d_O) = P((d_N)^2 < (d_O)^2)$$

$$= P((d_N)^2 + (X)^2 - 2(d_O X)\cos\Theta < (d_O)^2)$$

$$= P(X < 2(d_O)\cos\Theta)$$

$$= \int_{-\pi/2}^{\pi/2}\int_0^{2(d_O)\cos\Theta} c(X,\Theta)\,dX\,d\Theta \qquad (6)$$

$$P(d_N < d_O) = 2\int_0^{\frac{\pi}{2}}\int_0^{2d_O\cos\Theta} c\,(x,\Theta)\,dx\,d\Theta$$

$$= 2\int_0^{\frac{\pi}{2}}\int_0^{2d_O\cos\Theta}\left(\frac{\alpha^{\varphi}}{\Gamma(\varphi)}x^{\varphi-1}e^{-\alpha x}\right)\left(\frac{1}{2\pi I_0(\mathrm{k})}e^{k\cos(\Theta)}\right)dx\,d\Theta$$

$$= \frac{\alpha^{\varphi}}{\pi I_0(\mathrm{k})\,\Gamma(\varphi)}\int_0^{\frac{\pi}{2}} e^{k\cos\Theta}\int_0^{2d_O\cos\Theta} x^{\varphi-1}e^{-\alpha x}\,dx\,d\Theta.$$

Let $t = \cos\Theta$, $dt = d\cos\Theta = -\sin\Theta d\Theta$.

Because $\cos^2\Theta + \sin^2\Theta = 1$, $d\Theta = \frac{1}{-\sin\Theta}\,dt = -\frac{1}{\sqrt{1-t^2}}\,dt.$

Therefore:

$$P(d_N < d_O) = \frac{\alpha^{\varphi}}{\pi I_0(\mathrm{k})\,\Gamma(\varphi)}\int_0^1 \frac{1}{\sqrt{1-t^2}}\,e^{kt}\int_0^{2d_O t} x^{\varphi-1}e^{-\alpha x}\,dx\,dt. \qquad (7)$$

APPENDIX 3
Parameter Estimation for the von Mises Distribution

Turning to our tests of move direction, the direction of each move in the sample can be represented by a vector with direction **Θ** whose length is one (unit vector). The use of unit vectors conforms to the theoretical assumption that move direction and move length are independent. Summing all of the sample vectors results in a vector **R**, where $\boldsymbol{\Theta_R = \tan^{-1}\frac{1/_n \Sigma \sin \Theta_i}{1/_n \Sigma \cos \Theta_i}}$ is a measure of the mean move direction. The length of vector **R** also reflects the extent of clustering in the sample's mean direction.

This clustering is analogous to the variance in non-directional data. Standardizing by the number of observations in the sample yields an index $\mathbf{\overline{R}}$ with a value between zero and one. $\mathbf{\overline{R}} = \frac{R}{n} = \frac{\sqrt{(\Sigma \sin \Theta_i)^2 + (\Sigma \cos \Theta_i)^2}}{n}$, and $\mathbf{\overline{R}}$ is a function of the concentration parameter $\boldsymbol{k}$ by virtue of $\overline{R} = \frac{I_1(\hat{k})}{I_0(\hat{k})}$, where $\mathbf{I_0(\boldsymbol{k})}$ is a modified Bessel function of the first kind and zero order. Solving for kappa requires numerical approximation. To accomplish this, we employed the circular statistics package found at http://cran.r-project.org/web/packages/circular/circular.pdf.

Of the 1,140 students in the subsample, there are 1,086 unique beginning addresses. We assume some families have multiple students enrolled in the school, and further, that a single address represents a single family. For the analysis which follows, "families" refers to the 1,086 individual addresses. For the sample of relocating families in the current study, $\mathbf{\Theta_R}$ equals **0.081 radians**, or **4.64 degrees**. The clustering index $\mathbf{\overline{R}}$ equals **0.295**, yielding concentration parameter $\boldsymbol{k} = \mathbf{0.6184}$. For the von Mises distribution of the parent population when n is large and $\boldsymbol{k} = \mathbf{0}$, the statistic $\mathbf{2n\overline{R}^2}$ is approximately χ^2 distributed with two degrees of freedom. In this test, the value is **189.5**, which is far above the cutoff value of **5.99** for **p=0.05**.

Given a move direction bias, we next test the assumption that the move directions are biased toward the school. This test assumes the school is the attractor and tests whether or not we can reject that assumption. The 95 percent confidence interval around the school direction can be written as $\mathbf{0 \pm 1.96/\sqrt{nk\overline{R}}}$ = $\mathbf{0 \pm 1.96/\sqrt{(1086)(0.6841)(0.295)} = 0 \pm 0.139}$ **radians**. Because $\mathbf{-0.139 < \Theta_R < 0.139}$, we accept the hypothesis (i.e. cannot reject) that the move directions are concentrated toward the school.

NOTES

1. Santa Ana is 78.2% Hispanic or Latino and has a per capita income of $16,374 vs. $34,057 for entire country. U.S. Census Bureau (2016), *Santa Ana City, California* [QuickFacts Table], retrieved from http://census.gov/quickfacts/qfd/states/06/0669000.html.

2. The school's original preferred location was Los Alamitos, which has a per-capita income over twice that of Santa Ana. However, political support was lacking and the cost of space was prohibitive. See Terence Loose (2011), Artistic New World, *Coast Magazine*, retrieved from http://www.coastmagazine.com/articles/arts-2009--.html.

3. This result can probably be generalized to private schools that operate without catchment areas if the costs of attending the private school are similar to those of attending charter schools.

4. The term "urban redevelopment" is an inexact term. As a reasonable reference source for common vernacular, defines "redevelopment" as "any new construction on a site that has pre-existing uses." Variations on redevelopment include "adaptive reuse" which describes the conversion of older structures to new, more marketable uses. The school received financial assistance from the state of California to repurpose campus buildings as an "infrastructure project" specifically designed to revitalize Santa Ana's underutilized downtown area. Accordingly, OCSA's campus is a near-model of adaptive reuse. The main classroom building and two other principal school buildings along Main Street were originally used as banks. Each still has its original vault, and these spaces are used as teacher work rooms. The vault in the main tower has also been used as an octagonal theatre. A fourth major campus building, Symphony Hall, was built in 1922 as a Christian Science church before being adaptively reused as a performance space.

5. Bartley R. Danielsen, David M. Harrison, and Jing Zhao (2014), It Makes a Village: Residential Relocation After Charter School Admission, *Real Estate Economics*, *42*, p. 1013, http://dx.doi.org/10.1111/1540-6229.12074.

6. Bartley R. Danielsen, Joshua C. Fairbanks, and Jing Zhao (2015), School Choice Programs: The Impacts on Housing Values, *Journal of Real Estate Literature*, *23*(2), pp. 207-32, http://dx.doi.org/10.5555/0927-7544.23.2.207.

7. Charles M. Tiebout (1956), A Pure Theory of Local Expenditures, *Journal of Political Economy*, *64*(5), pp. 416-24, http://dx.doi.org/10.1086/257839.

8. Thomas J. Nechyba (1999), School Finance Induced Migration and Stratification Patterns: The Impact of Private School Vouchers, *Journal of Public Economic Theory*, *1*, pp. 5-50, http://dx.doi.org/10.1111/1097-3923.00002; Nechyba (2000), Mobility, Targeting, and Private-School Vouchers, *American Economic Review*, *90*, pp. 130-46, http://www.jstor.org/stable/117284; Nechyba (2003), School Finance, Spatial Income Segregation, and the Nature of Communication, *Journal of Urban Economics*, *54*, pp. 61-88, http://dx.doi.org/10.1016/S0094-1190(03)00041-X; Maria M. Ferreyra (2007), Estimating the Effects of Private School Vouchers in Multidistrict Economies, *American Economic Review*, *97*, pp. 789-817, dx.doi.org/10.1257/aer.97.3.789.

9. For examples of such work, see: Michael L. Walden(1990), Magnet Schools and the Differential Impact of School Quality on Residential Property Values, *Journal of Real Estate Research*, *5*, pp. 221-30, retrieved from http://pages.jh.edu/jrer/papers/pdf/past/vol05n02/v05p221.pdf; Randall R. Reback,(2005), House Prices and the Provision of Local Public services: Capitalization under School Choice Programs, *Journal of Urban Economics*, *57*, pp. 257-301, http://dx.doi.org/10.1016/j.jue.2004.10.005; Gabrielle Fack and Julien Grenet (2010), When Do Better Schools Raise Housing Prices? Evidence from Paris Public and Private Schools, *Journal of Public Economics*, *94*, pp. 59-77, http://dx.doi.org/10.1016/j.jpubeco.2009.10.009; Stephen Machin and Kjell G. Salvanes (2010), *Valuing School Quality via a School Choice Reform* (CEE Discussion Papers No. CEEDP0113) http://ftp.iza.org/dp4719.pdf; John D. Merrifield, Kerry King-Adzima, Todd Nesbit, and Hiran Gunasekara (2011), The Property Value Effects of Universal Tuition Vouchers, *Journal of Housing Research*, *20*, pp. 225-238, http://www.jstor.org/stable/24861529; Eric J. Brunner, Sung-Woo Cho, and Randall R. Reback (2012), Mobility, Housing Markets, and Schools: Estimating the Effects of Inter-district Choice Programs, *Journal of Public Economics*, *96*, pp. 604-614, http://dx.doi.org/10.1016/j.jpubeco.2012.04.002; Robert J. Shapiro and Kevin A. Hasset (2013), *The Economic Benefits of New York City's Public School Reforms, 2002 – 2013* (Sonecon Report No. 1-31), retrieved from http://www.sonecon.com/docs/studies/Report_on_Economic_Benefits_of_NYC_Educational_Reforms-Shapiro-Hassett-Final-December2013.pdf; Amy E. Schwartz, Ion Voicu, and Keren M. Horn (2014), Do Choice Schools Break the Link Between Public Schools and Property Values? Evidence from House Prices in New York City, *Regional Science and Urban Economics*, *49*, pp. 1-10, http://dx.doi.org/10.1016/j.regsciurbeco.2014.08.002; Susanne E. Cannon, Bartley R. Danielsen, and David M. Harrison, (2015), School Vouchers and Home Prices: Premiums in School Districts Lacking Public Schools, *Journal of Housing Research*, *24*(1), pp. 1-20, retrieved from http://aresjournals.org/doi/abs/10.5555/1052-7001.24.1.1. A single study found no effect on property values for public charter elementary schools in Dayton, Ohio, and a negative property value effect for public charter (and public non-charter) high schools in the same community. See John Horowitz, Stanley Keil, and Lee Spector (2009), Do Charter Schools Affect Property Values? *The Review of Regional Studies*, *39*, pp. 297–316, retrieved from http://journal.srsa.org/ojs/index.php/RRS/article/viewFile/201/156.

10. El Sol Santa Ana Science and Arts Academy is a K-8 public charter school located at 1010 N. Broadway Street, Santa Ana, CA 92701. Orange County Educational Arts Academy is a K-8 public charter school located at 825 North Broadway Santa Ana, CA 92701-3423. California Department of Education (2015). School Accountability Report Card [data file], retrieved from http://www3.cde.ca.gov/researchfiles/sarc/sarc1415/schengr.txt; California Department of Education, Find a SARC [code book], retrieved from http://sarconline.org/ during the 2014-2015 school year. These schools had 884 and 568 students, respectively, OCSA enrolled 1920 students in the 2015-2016 school year.

11. Bartley R. Danielsen, David M. Harrison, and Jing Zhao. (2014), It Makes a Village: Residential Relocation After Charter School Admission, *Real Estate Economics*, *42*, pp. 1008-1041, http://dx.doi.org/10.1111/1540-6229.12074.

12. General Admissions FAQ for OCSA found at http://www.ocsarts.net/page.aspx?pid=429, paragraph 21.

13. Linear distance was found to be highly correlated with drive distance and drive time for the school studied in Bartley R. Danielsen, David M. Harrison, and Jing Zhao (2014), It Makes a Village: Residential Relocation After Charter School Admission, *Real Estate Economics*, *42*, pp. 1008-1041, http://dx.doi.org/10.1111/1540-6229.12074. The correlation with drive distance was .99 and the correlation with drive time was .95. These high correlations appear to be driven by the fact the students arrive at a common destination. For methodological reasons, linear distances are required for much of the analysis which follows. Specifically, part of the analysis depends upon the move direction for each student, which is calculated as an angle, which is dependent upon linear vectors that denote both distance and direction.

14. Some students moved more than once. 19.4% of the students who moved did so at least twice. 2.7% moved at least three times. For this analysis, we treat the student's address at the time of admission to the school as the first address (R_{Old}) and the final address of record as R_{New}.

15. We also conduct analogous tests for the subsample (1,140 unique student obs.) with original distance (and ending distance) of less than or equal to 50 miles from school. The average value of (d_O-d_N) is 1.54 miles and the p-value of the one-sided t-test (H_A: mean > 0) is 0.000. The sign test shows that 609 of the 1,140 local movers actually moved towards the school, and 531 moved away from the school. If the true underlying Pr(d_O-d_N>0)=0.5, the chance of observing 609 or more positive values of (d_O-d_N) is p=0.0113. Finally, the Wilcoxon sign-rank test rejects the null (H_0: mean=0) with a one-tailed p-value of 0.0001.

16. The von Mises distribution is also known as a circular normal distribution. This distribution is commonly used with directional data. For example, see, William A. V. Clark , Youqin Huang, and Suzanne Withers (2003), Does Commuting Distance Matter? Commuting Tolerance and Residential Change, *Regional Science and Urban Economics*, *33*, pp. 199–221, http://dx.doi.org/10.1016/S0166-0462(02)00012-1.

17. William A.V. Clark and James E. Burt (1980), The Impact of Workplace on Residential Relocation, *Annals of the Association of American Geographers*, *70*, pp. 59–67, http://www.jstor.org/stable/2562825; William A. V. Clark , Youqin Huang, and Suzanne Withers (2003), Does Commuting Distance Matter? Commuting Tolerance and Residential Change, *Regional Science and Urban Economics*, *33*, pp. 199–221, http://dx.doi.org/10.1016/S0166-0462(02)00012-1.

18. William A.V. Clark and James E. Burt (1980), The Impact of Workplace on Residential Relocation, *Annals of the Association of American Geographers*, *70*, table 1, p. 206, http://www.jstor.org/stable/2562825; William A.V. Clark, Youngquin Huang, and Suzanne Withers (2003), Does Commuting Distance Matter? Commuting Tolerance and Residential Change, *Regional Science and Urban Economics*, *33*, pp. 199–221, http://dx.doi.org/10.1016/S0166-0462(02)00012-1.

19. To test whether this difference is statistically significant, we utilize the bootstrapping technique described in Danielsen, Harrison, and Zhou. We find that the difference between the parameter value for 9th graders and other grades is statistically significant, but other grade differences are statistically insignificant.

20. Determining why families in various grades demonstrate a stronger attraction to the school requires additional research, but it would seem to be particularly interesting planners and to developers who are seeking to use school choice programs to create more valuable urban amenities.

ABOUT THE AUTHORS

Dr. Bartley R. Danielsen is an associate professor of Business Management at North Carolina State University and the founder of Environmentalists for Education Reform (thegreenapples.org). His research interests focus on financial markets, real estate, and urban planning. Dr. Danielsen is the co-author of *Foundations of Financial Management*, one of the world's best-selling finance textbooks now in its 16th edition. His academic research has appeared in leading academic finance and real estate journals.

Dr. David M. Harrison is the Howard Phillips Eminent Scholar Chair in Real Estate at the University of Central Florida, and past president of the American Real Estate Society (ARES). He is the co-editor of the *Journal of Real Estate Literature* and the author of more than 50 peer-reviewed journal articles and research reports. In 2007, Dr. Harrison was awarded the William N. Kinnard award by the American Real Estate Society for "substantial contributions to the field of real estate research achieved under the age of 40."

Dr. Jing Zhao is an assistant professor in the School of Business at Portland State University. Dr. Zhao has published empirical articles in leading academic finance journals. She has also published articles in real estate journals focusing on the connections between school choice programs, real estate development, and the environment.

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The authors welcome any and all questions related to methods and findings.

EDCHOICE

111 MONUMENT CIRCLE
SUITE 2650
INDIANAPOLIS, IN 46204
317 681 0745

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