Why Are Private Schools Small?
School Location, Returns to Scale, and Size

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Abstract

Private schools are, on average, a third of the size of public schools. But why are they small? Two possible explanations are differences in demand, or differences in production. If the returns to scale are similar for private and public high schools, and increase in school choice through private school vouchers could lead to larger private high schools. This would be a demand effect. Private schools are smaller because fewer people want to go to them. Using cost estimates for public schools from Ledyard (2004), I can account for approximately 70% of the difference in size between public and Catholic high schools. I hold costs fixed, and use data on private school location, size and affiliation to predict the size of Catholic schools.

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I would like to thank for helpful comments.

1 Introduction

It is a well known fact that private schools are on average smaller than their public school counterparts. But what causes this difference? The answer is interesting not only from an academic perspective, but may also have important implications for the market for schooling in the event of a large scale voucher program, or other school choice program. Some argue that private schools are smaller because smaller schools are better, and more efficient. But what if private schools are smaller simply because fewer people demand their services, and it is difficult for them to capture the scale economies available to public schools? In the event of a large scale voucher program, it is possible that private school size will increase dramatically. Understanding the determinants of private school size will allow us to better predict the likely effects of these programs to the market for schools.

The average public school is 1473 students, while the average private school is 520 students. Private school markets are further segmented by type in terms of size. Private school size also differ size. Catholic schools are larger than other private schools. To understand the market for schooling, it is important to understand what causes these structural differences in school size. Are they caused by differences in production or differences in demand? The answer to this question has huge implications for the change in the market for schooling in the event of a large scale choice program. If the differences in size arise from differences in production, then the introduction of a choice program could cause a large change in the schooling market.

An important part of the production for schooling is increasing returns. Larger schools, particularly high schools, are able to offer a larger variety of courses such as more Advanced Placement courses, more arts classes, and more sports teams. Public schools are required to serve the students in their district. By having more students, public schools are able to better group students by ability and interest. This allows them to increase benefits to households while not increasing costs. A small school can possibly offer the same variety of classes as a large school, but the cost per student will be higher. In previous literature, I have estimated the costs net of benefits from these scale economies. I find evidence that scale economies are important in the market for public schools. The estimation of these scale economies comes from the tradeoff between transportation costs and the scale economies.

Both of these traits of the market for public schooling suggest possible avenues for the smaller school sizes. One possible channel is the difference in effective density of areas from which private schools draw students. If 10% of students attend private schools, and they are evenly distributed over space, then the density that the private schools have to draw from is only 10% of the density of the public schools. This decreased density will increase the transportation costs necessary to produce a school of a given size. An alternative explanation is that private schools are able to choose their student composition, and in doing so, they can group students by interest and ability. Because of this ability to sort, private schools maybe able to offer exactly the classes that their students desire without increasing size.

Previous literature on choice programs have largely ignored the market structure for schooling, and has focused mainly on the changes in peer groups for schooling between private and public schools ((Epple and Romano 1998), (Ferreyra 2001), (Nechyba 2000)). Other work has studied the effects of competition on productivity in public schools ((Hoxby 2000)). In my work, I study the underlying production technology for schools, and abstract from these complications. The models that I present below are already quite computationally intensive, and as a result, necessitate simplifying assumptions.

I follow closely the industrial organization literature on scale economies. A key feature in the market for schooling is transportation costs. It can be not only costly monetarily, but also in terms of time to take a student to school everyday. I exploit this feature to estimate the cost functions in this paper. Building on Ledyard (2004), which estimates these costs for public schools, I exploit the tradeoff between scale economies and transportation costs. Caselli and Coleman (2001) cite reduction in transportation costs as one reason that for the increases in education quality in the 20th century. I also build on Berry (1992) and Bresnahan and Reiss (1990) in that I estimate the cost function by looking at counts of schools by location and type. My problem is simpler than these two because I am able to look at a modified planner's problem, and thus, I need not worry about markups or strategic interactions. However, my problem is more complicated in that I look at multi-plant problem, adding to the complexity of location decisions. Downes and Greenstein (1996) and Barrow (2001) both look at location decisions of private schools to understand entry/exit behavior. While I also use location decisions, I use exact location of schools, and not simply neighborhood or zipcode location. The study also follows Holmes (2002) which studies the importance of transportation costs and increasing returns in a multi-plant location model.

I focus primarily on the difference in catholic and public school size. I find that much of this difference can be explained by differences in effective density that the schools face. In light of this, it is not that public and private schools face different cost structures, but rather that have similar technology and face different demand conditions. This means that the introduction of a global choice program is likely to have an equalizing effect on school sizes across types, at least between public and catholic schools.

In the next section, I document the facts about school size in the United States, and the differences in public and private school size. In section 3 I present a simple model of school size with scale economies. In section 4 I develop a model which allows for a richer geographical structure, cost structure, and variation in demand. In section 6 I conclude.

2 School Size in the United States

Private schools in the United States are much smaller than the public schools. In this section, I will document the facts about the differences in school size for high schools. In general, I will define a high school as any school that serves any student in 9th-12th grades. Many schools serve students other than simply high school students. For school size, I used the number of 9th -12th students in the school. This is an additional avenue through which schools may capture scale economies. In the analysis that follows, I will ignore this possibility.

2.1 The Data

The data in this section comes from several sources. The data on private school location, size, and affiliations comes from the Private School Survey (PSS), 1999-2000 supplied by the National Center for Education Statistics (NCES). There are 29,159 schools in the data set. Of those, 8,142 are high schools (they serve at least 1 9th-12th grader). Of these high schools, 1,261 are Catholic, 4,994 are affiliated with some other religion, and 1,887 are Nonsectarian. Almost 2 million High School Students are represented in this data set. This data set includes specific religious affiliation, the number of students in each school by grade, and the location (street address.) In addition for Catholic schools, the data set includes the Diocese that the school is affiliated with, and the type of Catholic school. Catholic schools are either Parochial, Diocesan, or Private. Parochial schools are schools run by a local parish, Diocesan schools are run by the central Diocese, and private Catholic schools are privately controlled independent of the either a local parish or the Diocese.

The public school data comes from the NCES's Common Core of Data (CCD) from 1999-2000. This data set is comprised of two parts. The first is the Local Education Agency (LEA) database, which lists all the school districts in the US. The second, is the Public School Universe (PSU). This lists all the public schools. There are approximately 15,000 public high schools in the US. Population data comes from Census 2000, summary file 3. This includes data on the number of students in each county and block group.

2.2 School Sizes

Private schools are smaller than public schools. Weighted by the number of 10th graders in the school, the average private school is 520 students, the average public school size is 1473 students. Public school sizes vary considerably. The smallest schools have 9 students, the largest schools have over 5000 students. The smallest private schools have 1 student, and the largest private schools have about 2,800 students. Table 2 shows the average school size by affiliation. The average size of a Catholic schools, 753 students, is considerably larger than other types of private schools.

As I argued before, it is possible that the size of schools differs simply because the effective density for public and private schools differs. To investigate this possibility, I look at public and private school size by the decile of density. For public schools, I use the number of 9th-12th graders per square mile in the district. For private schools, I use the number of 9th-12th graders attending private school in the county. Table 3 shows the average school size for each decile. Each decile contains 10% of the students in that type of school. As you can see, simply controlling for the density of the district or county does not get rid of these differences. The 90-10 ratio for private schools is 2.5, while the 90-10 ratio for public schools is 2.2. The 90-10 ratio is bigger for private schools than it is for public schools. We can further break this down by affiliation. Looking at Catholic schools independent from other private schools shows an interesting pattern. Catholic school size increases with density while the average size for other private schools do not.

We can also look at this data graphically. Figure 1 shows the log of public school size as a function of the log of density. Figure 2 shows log average school size vs. density of all private schools. Figure 3 shows log size vs. density of Catholic Schools, other religious schools, and nonsectarian schools. The patterns here are visually striking: catholic school size increases by density, other private school size does not. It is also useful to further decompose the catholic schools by type, as shown in Figure 4.

3 A Simple Model

The following model follows closely those used in Ledyard (2004) to estimate scale economies for public schools. I will use this model to estimate the scale economies for diocesan and parochial schools. This will require several assumptions which I discuss below in order to take the model to data. I will discuss the plausibility of these assumptions below as they relate to catholic schools, and then will explore modifications of these assumptions, and the implications.

Here, I present a very simple model of school size with scale economies. The model is a social planner's version of the classic location model of Salop (1979) model.[1] The diocese is the cental authority, and will choose school size. Let a diocese be an infinite line. Students are located on the line with uniform, exogenous density, m. In order to establish a school, the diocese must pay a fixed cost, F.

The diocese must also pay for the transportation of students to schools. The transportation cost is linear in the distance from the student's location to their school. The cost to transport one student who lives one unit of distance from their school is τ, I call this the student-year-mile cost. This transportation cost may be viewed as the amount the district must pay to transport students (i.e. the costs of buses and drivers). Alternatively, this transportation cost may be a more comprehensive cost. It may include the opportunity cost of student's or parent's time. This interpretation requires that the diocese cares about the costs that accrue to parents and students, and not simply the direct costs to the school.

[1] Syverson (2003) uses a similar model)

I consider the decision of a diocese planner who chooses school size and location to minimize the average cost of schooling and transportation. Let d be the distance between schools and s be the size of a school. School size is then the product of the distance between schools and the density of students, ie $s = dm$. The diocese chooses d to minimize average cost as follows:

$$\min_d \frac{d}{4}\tau + \frac{F}{dm}.$$

The first term in this expression is the average transportation cost (put the school in the middle of the segment of size d and the average distance transported is then half of that distance). The second term is the average cost of establishing a school. The solution, in terms of size, is:

$$(1) \qquad s = m\sqrt{\frac{4F}{m\tau}}.$$

This shows that the school size is increasing in density, m, and the fixed cost, F, and decreasing in transportation cost, τ. Because school size is increasing in density, it is also increasing in the number of students in the district, given a fixed district size. In order to increase school size, the district must increase transportation distances. This tradeoff between transportation costs and scale economies is the focus of this paper, even in the more complex model.

Taking logs of Equation 1, and rearranging gives:

$$\log(s) = \frac{1}{2}\log(\frac{4F}{\tau}) + \frac{1}{2}\log(m).$$

This gives a simple way to solve for the fixed cost, F. Looking at school size as a function of density, the first term is the intercept. Figure 4 shows the relationship between log size and log density for diocesan, parochial, and private Catholic high schools in the U.S. by type. This theory tells us that the coefficient on the density should be 0.5 (the slope is actually 0.17 (standard error is 0.03)). The figure shows the actual regression line. The intercept term can then be used to solve for F. I run a restricted regression, requiring the coefficient on log-density to be 0.5. The intercept term of this regression is 5.04 which is equal to $\frac{1}{2}\log(\frac{4F}{\tau})$, giving $F/\tau = 5,965$. For public schools, the intercept is 5.06, giving $F/\tau = 6,146$.

These intercept terms are surprisingly close, given the large differences in size. If the slope coefficients were closer, it might be possible to conclude from this model alone that the technology the schools face is the same. However, the large deviation in slope from the 0.5 prediction suggests that the model is missing some key elements. The most obvious is that catholic schools cannot compel students to attend as public schools can. There is no fixed attendance area, and school size will be determined jointly by parental demand and school administrators. In addition, it is probable that transportation costs are not borne by administrators but by households. In order to compensate for these differences, in addition to other real world features, in the next section, I develop a richer model of these schools.

4 A Richer Model

In this section, I add three key features to the first model, a richer geography, a more flexible cost function, and a very simple demand model. This is similar to Ledyard (2004) in costs and geography, but deviates in the demand structure. Here, demand is (somewhat) endogenous, where in previous work, it was exogenous. I will begin by introducing the richer geography and cost structure, and then introduce the richer, although still limited, demand structure.

As for the richer geography, students are now located in a two-dimensional plane in an arbitrary way. Students are located in a dioceses at a discrete number of points on a grid, I. Let $i = 1, 2, .., I$ be the index for locations within a dioceses. Let m_i be the total number of students who live at location i. The total number of students in the diocese is $M = \sum m_i$. Figure **??** shows what an example dioceses would look like in terms of location of students.

As for the richer cost structure, I allow a flexible form for the average cost function. Let $a(s)$ be the average cost of educating a child in a school of size s. Assume the parametric form:

$$a(s) = \beta_0/s + \beta_1 + \beta_2 s + \beta_3 s^2.$$

A decreasing average cost function captures two important features of schooling costs. One is the standard fixed cost portion of schooling. The second is that larger schools are also able to offer more programs that families enjoy. These include more advanced placement classes, athletic teams, and music programs. These additional services may not show up in standardized test scores, but are important when calculating the size of scale economies.[2] Figure 5 shows the average number of sports offered by schools of different sizes and affiliations. It clearly shows that for public and Catholic schools, larger schools offer a larger variety of sports teams.

As in the simple model, the school must pay for transportation of students to schools. The transportation cost is again linear in the distance from the student's location to their school. Unlike the simple model, or previous work, households and schools will share the cost of transporting students to schools. The cost to dioceses is τ_d, and the cost to households is τ_h. Each of these is a student-mile-year cost. The household transportation cost figures in very prominently in the demand for schooling. I discuss its role in the next section.

4.1 Public and Other Private Schools

Public school and other private school location is exogenous in this model. When the Catholic schools are deciding where to locate, and what size to be, they will take the location of public schools and other private schools as given. By simplifying the other schools in this fashion, it will allow me to solve the model. Allowing all schools to make simultaneous decisions in this location model is intractable.

4.2 Demand for Schools

In order to keep the model tractable, I allow for only very simple demand for catholic schools. Household location is exogenous. While this is an extreme assumption, it allows for simplicity in solving the model. An exogenous fraction of households, α_1, would be willing to send their child to catholic school if they lived right next to the Catholic school.[3]

Demand for Catholic schools varies among Catholic school families only through transportation costs. As stated above, households must pay a portion of the transportation costs to get the students to school, specifically,τ_h. This transportation cost is linear in the

[2]While I do not model this explicitly, the idea is consistent with variety increasing with market size as in Dixit and Stiglitz (1977).

[3]Previous work has found that the demand of households for Catholic schools is different than demand for other schools.

great circle distance that the household lives from the school.[4] If a student is admitted to more than one catholic school, then they will always choose the one closest to them. For this model,in the absence of transportation costs, all catholic schools are the same from the families point of view.

In addition, because public and other private schools are taken as given when households make their decisions, the value of the households outside option is constant with respect to the location and size decisions of the Catholic school. This, coupled with the transportation cost, implies that the fraction of households will send their child to Catholic school decreases with the distance the household lives from the Catholic school.

4.3 The Diocese's Problem

The Diocesan administrator chooses the number, the location, and the size of schools, given demand to minimizing total cost. In order to support this assumption, one can simply assume that Catholic school tuition is constant, and the schools maximize profits. The administrator may locate schools at any point on the population grid. Schools are numbered 1 through N, where N is the number of schools in the dioceses (this is endogenous). Let j_n be the location of school n. In addition to choosing the location of and the number of schools, the administrator must choose which students go to which school, given the constraints of demand (i.e. students will choose the closer school if given the option of two schools). Let D be an I by N matrix where element (i, n) gives the fraction of students at location i that attend school n. The size of school n, which is a function of j_n and D, is denoted by s_n. Let $t(j_1, ..., j_N, D)$ be the total miles traveled as a function of school locations and the attendance matrix. The total transportation cost for the dioceses is then $\tau_d \; t(j_1, ..., j_N, D)$.

4.4 Solving the planner's problem

Now we turn to solving the problem. The problem can most easily be understood in two steps. In the first step, the superintendent chooses the number of schools. In the second step, he decides the location of the schools and assigns students to schools. Working

[4]By using great circle distances, I avoid having to calculate distances using actual routes traveled, which is a considerable task.

backward, given the number of schools, the administrator chooses the location of the schools, $j_1, ..., j_N$ and the attendance matrix, D, to solve the following:

$$(2) \quad c(N) = \min_{j_1,...,j_N,D} \sum_{n=1}^{n=N} a(s_n)s_n + \tau_d \; t(j_1, ..., j_N, D).$$

Thus, $c(N)$ is the minimized cost of supplying N schools. Given these costs, the administrator chooses the number of schools to minimize the cost. Let c^* be the minimized cost, and N^* be the optimal number of schools. Then:

$$c^* = \min_N \; c(N).$$

4.5 Solution to Stage 2 Problem

I now describe the algorithm used to calculate the costs. To calculate these costs, I explain how to solve the model for the locations of schools, and the allocation of students to schools that minimizes the total cost, for one school and for two schools. I do an exhaustive search over the possible combination of locations for schools. Given the school locations, then the allocation of students to schools can be determined.

To solve for the cost when there is only one school in the district, notice first that every student in the district goes to this school. The cost function is then:

$$c(1) = \min_{j_1,D} Ma(M) + \tau \; t(j_1, D),$$

where M is the total number of students in the district. Since all students go to the school, assignment matrix, D, is trivial, and is just a column of ones. The only decision that the administrator needs to make is where to locate the school. Since school size is fixed, the choice reduces to the minimization of the transportation distances. Thus, the superintendent chooses school location to minimize the total distance between students and schools.

When there are two schools the division of students to schools changes costs. Let s_1 be the size of school 1. Then the size of school 2 is $M - s_1$. Then cost function takes the form:

$$(3) \quad c(2) = \min_{j_1,j_2,D} s_1 a(s_1) + (M - s_1)a(M - s_1) + \tau \; t(j_1, j_2, D).$$

For simplicity, first consider the case of constant marginal cost ($\beta_0 > 0$, $\beta_1 > 0$, and $\beta_2 = \beta_3 = 0$). The cost function reduces to:

$$c(2) = \min_{j_1, j_2, D} s_1[\frac{\beta_0}{s_1} + \beta_1] + (M - s_1)[\frac{\beta_0}{M - s_1} + \beta_1] + \tau\ t(j_1, j_2, D).$$

Which reduces to:

$$c(2) = \min_{j_1, j_2, D} 2\beta_0 + M\beta_1 + \tau\ t(j_1, j_2, D).$$

The first term is twice the fixed cost and the second is the marginal cost times the total number of students in the district. These do not change with the location or size of the two schools. For the school cost, the size of each school does not matter, only the total number of schools, and the problem reduces to minimizing the transportation distances. This is achieved by sending each student to the school closest to them and arranging schools so they are close to students.

When the cost function is not constant marginal cost, then changing school sizes changes the average cost in the schools. Because size matters in this case, where students go to school is important. The lowest cost configuration may not be that in which all students go to the closest school. The change in cost from moving a student from school 2 to school 1 can be found by taking the derivative of equation 3. This gives:

$$(4) \qquad \frac{\partial c(2)}{s_1} = [s_1 a'(s_1) + a(s_1)] - [(M - s_1)a'(M - s_1) + a(M - s_1)] + t'.$$

The first two terms in equation 4 are the change in cost at school 1. Moving a student to school 1 will reduce the average cost in school 1 for all of the students who were already at that school. In addition, the new average cost must be paid for the additional student. The third and fourth terms are the change in costs at the second school. The last term is the change in transportation cost. Because the average cost function is decreasing, $a'(\cdot)$ is weakly negative.[5] Since only one student has moved, the change in transportation cost is just the difference between the distance the student had to travel to school 1 and the distance that the student has to travel to school 2 times τ. If equation 4 is less than zero, then it is cheaper to move the student from school 2 to school 1, even if school 2 is closer to the students home. There is an incentive for districts to smooth size across schools.

To computationally solve for the attendance matrix, D, I begin with all students in one school. I then rank the locations by the difference in distance to school 1 and school

[5] While the functional form of $a(s)$ does not dictate this, the data does.

2. If it is beneficial to put any students in the second school, it will be those students for whom the change in distance is the lowest. I thus order them in ascending order. School 2 is then filled up with students from locations starting with the location that has the lowest difference in distance (t' is the smallest). This is done until the total cost increases.

I then will take the model to the data and back out costs, and the demand parameters. I am in the process of doing this.

5 Estimation

In this section I explain the estimation procedeure. I estimate the fraction of households that attend Catholic school, α_1, and the fraction of the transportation costs that households must pay, τ_h. Remember, this τ_h can also be thought of a decay parameter. I do not estimate costs here. Because I am interested in understand wether we can explain the differences in the size of Catholic schools and public schools without resorting to differences in technology, the cost function is the same as was estimated in Ledyard (2004).

In order to estimate the parameters of the model, I solve the model for the number of schools, size, and location. I then use a Generalized Method of Moments to estimate the model. I match number, and size of schools to the observed number and size of schools.

5.1 Matching the Data to the Model

I will now explain how I match the data to the model. Locations are block group locations from Census 2000. For the location of the blockgroup, I use the internal latitude and longitude reported in the Census. This is sometimes a population centroid, but not always. To get the number students, I use the total number of students in the blockgroup who are in 9th-12th grades.[6] Private school location, size, and affiliation is taken from the Private Schools Survey (1990-2000).

[6]This comes from Summmary File 3.

6 Conclusion

Private schools are considerably smaller than public schools. The average private school is about a third of the size of the average public school. The difference in private school size across types of private schools is also pronounced. Catholic school size, and variety seems to more closely mimic the public schools. Other private schools are considerably smaller on average, and variety of sports teams does not vary with size in the same ways. It is possible that Catholic and public schools are more general-purpose schools. They respond to increased size by increasing variety, something that households value. Other private schools, by virtue of their size, cannot offer as large a variety, and thus must specialize, leading to large variety across schools, but little within school variation. To better understand the forces that drive this, it will be important to identify the reasons for these differences.

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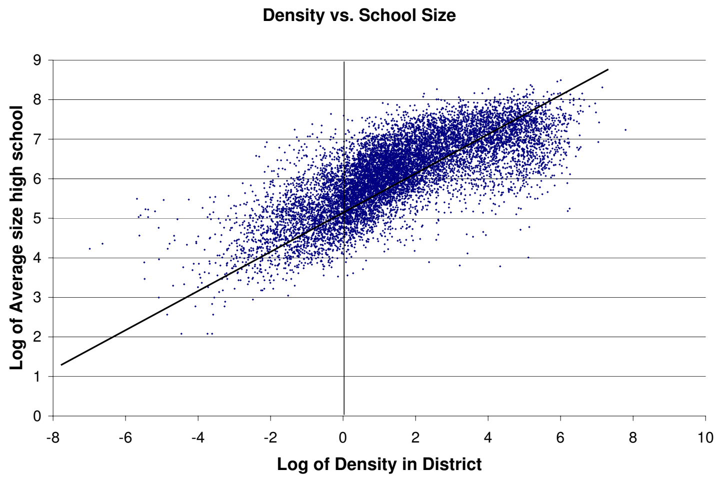

Figure 1: Public school size as a function of school district density.

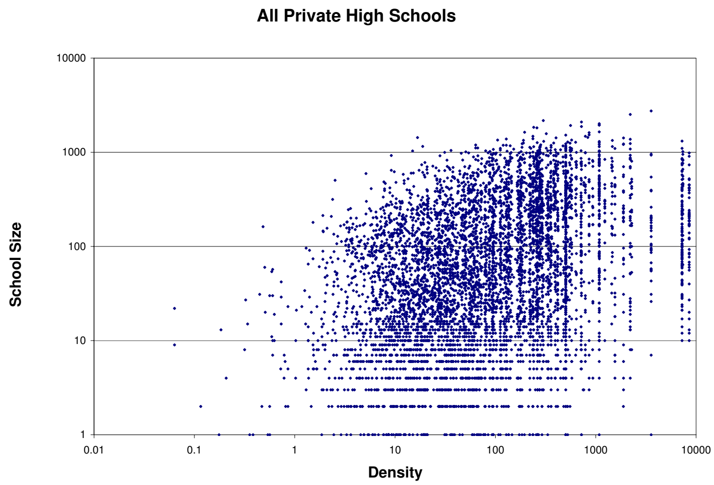

Figure 2: School size for all private schools as a function of the county density.

	Average Size	Min Size	Max Size	Std. Dev.	
Public		1499.87	9	5264	12149.87
Catholic		753.83	1	2748	9593.50
	Parochial	539.45	1	1140	2601.79
	Dicoean	777.75	1	2521	4959.82
	Private	785.66	1	2749	5144.10
Other Religious		241.42	1	1819	1995.69
Nonsectarian		324.18	1	1154	2936.32

Table 1: School Sizes by type.

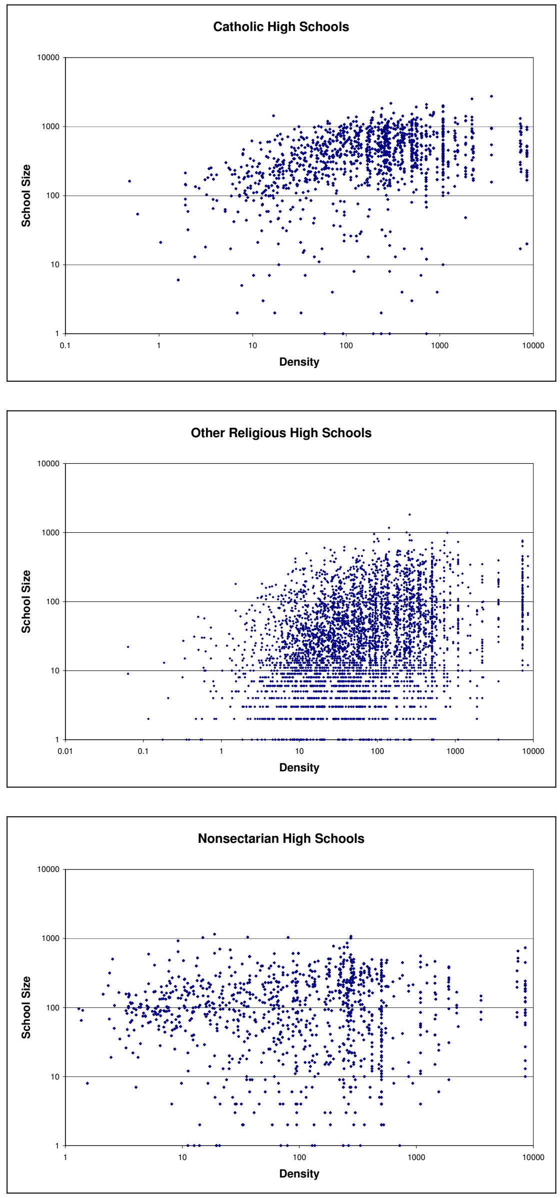

Figure 3: School size as a function of county density by religious affiliation.

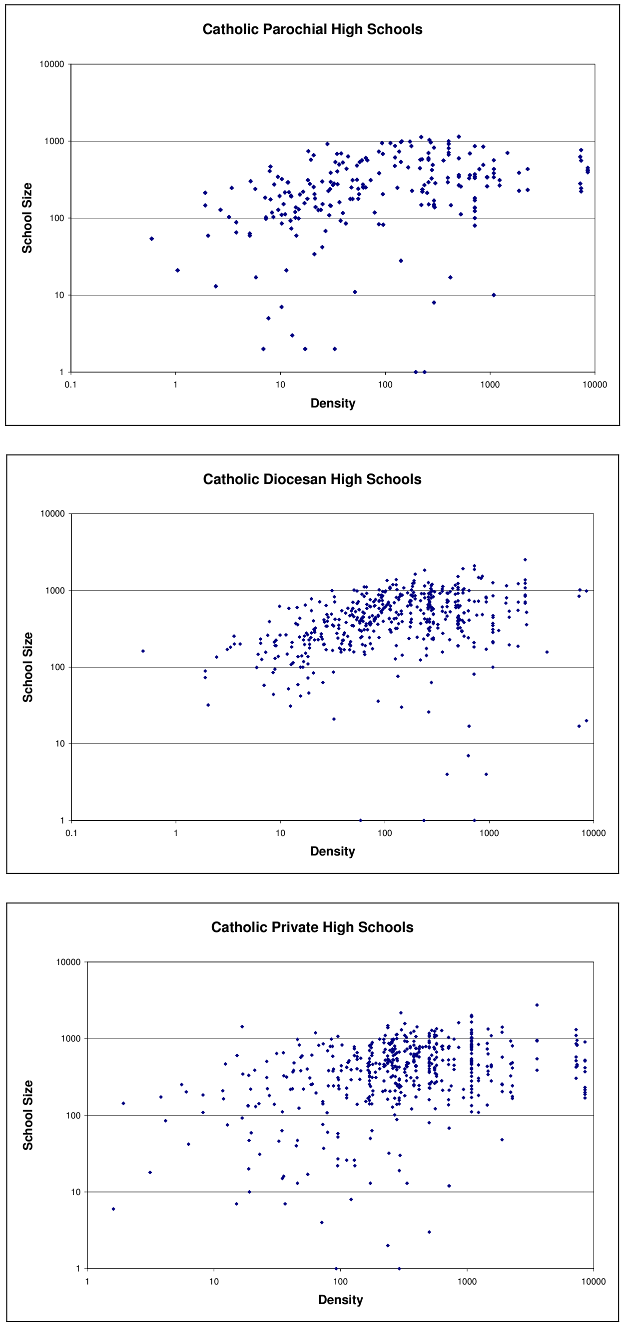

Figure 4: School size as a function of county density by Catholic school type.

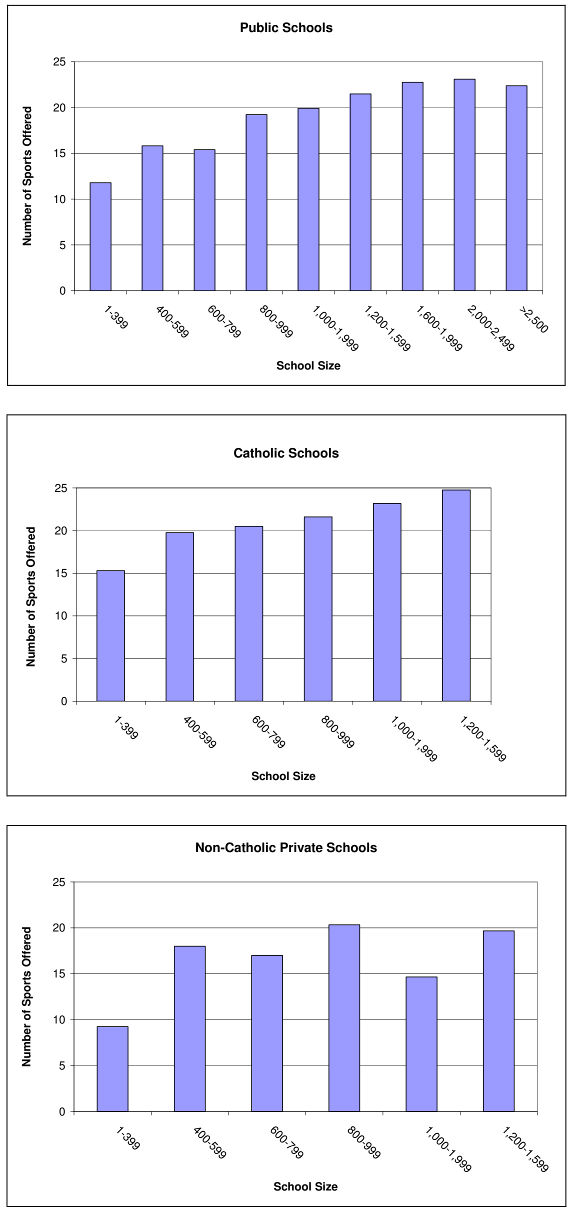

Figure 5: Average number of sports offered as a function of school size, by school affiliation.

	Average Size	Min Size	Max Size	Std. Dev.
Public	1499.87	9	5264	12149.87
Catholic	753.83	1	2748	9593.50
Other Religious	241.42	1	1819	1995.69
Nonsectarian	324.18	1	1154	2936.32

Table 2: School Sizes by type.

Decile	Public	Private	Catholic	Other Religious	Nonsectarian
1	552	270.15	453.36	119.58	273.09
2	859	300.10	449.26	163.85	298.45
3	1,185	405.04	593.28	202.34	258.43
4	1,351	479.94	728.85	258.35	240.53
5	1,547	544.11	753.26	224.50	297.14
6	1,736	620.68	779.51	444.60	402.66
7	1,867	555.33	777.47	211.53	250.24
8	1,841	543.98	759.97	250.65	227.35
9	1,878	734.92	895.42	359.29	181.05
10	2,355	716.00	924.65	308.23	299.53

Table 3: School Sizes by type.