THE EFFECT OF CLASS SIZE ON TEACHER ATTRITION:

EVIDENCE FROM CLASS SIZE REDUCTION POLICIES IN NEW YORK STATE

by

Emily Pas Isenberg *
U.S. Bureau of the Census

CES 10-05 **February, 2010**

The research in this paper was undertaken while the author was at Syracuse University.

Abstract

Starting in 1999, New York State implemented class size reduction policies targeted at early elementary grades, but due to funding limitations, most schools reduced class size in some grades and not others. I use class size variation within a school induced by the policies to construct instrumental variable estimates of the effect of class size on teacher attrition. Teachers with smaller classes were not significantly less likely to leave schools in the full sample of districts but were less likely to leave a school in districts that targeted the same grade across schools. District-wide class size reduction policies were more likely to persist in the same grade in the next year, suggesting that teacher expectations of continued smaller classes played a role in their decision whether or not to leave a school. A decrease in class size from 23 to 20 students (a decrease of one standard deviation) under a district-wide policy decreases the probability that a teacher leaves a school by 4.2 percentage points.

JEL Classification: I29, J45, J62

Keywords: class size, teachers, teacher attrition

* I thank Bob Bifulco for sharing New York State and federal class size reduction policy data with me, and Bill Duncombe, Thabo Mabogoane, and Tariq Al-Alawi for sharing New York State teacher and school data with me. This work was much improved by thoughtful suggestions from Dan Black, Bill Duncombe, Eric Isenberg, Jeff Kubik, Susanna Loeb, Jan Ondrich, and John Yinger. I thank the Spencer Foundation for financial support. The research in this paper was undertaken while I was at Syracuse University. Any opinions and conclusions expressed herein are my own and do not necessarily represent the views of the U.S. Census Bureau or Syracuse University. The research in this paper does not use any confidential Census Bureau information.

1. INTRODUCTION

Although the federal government, many states, and local districts have implemented class size reduction policies, we know little about how much teachers value small class size and how these policies have affected teacher attrition. Most research on teacher labor market effects of class size reduction has focused on California's statewide policy. This research has investigated increases in the share of inexperienced teachers and changes in the distribution of teacher characteristics across schools (e.g. Bohnstedt and Stecher 2002). A related branch of literature has examined how teacher salaries and school characteristics affect teacher attrition (e.g. Ondrich, Pas, and Yinger 2008, Hanushek, Kain and Rivkin 2004, Gritz and Theobald 1996, Mont and Rees 1996). However, prior research does not address the causal effect of class size on teacher attrition.

This paper addresses that question using data from New York State. Starting in the 1999-2000 school year, New York State implemented the federal class size reduction policy and a New York State policy, the Early Grade Class-Size Reduction Initiative. Both policies were targeted at schools with disadvantaged or low achieving students and large classes, and were directed at the early elementary grades (kindergarten through grade three).[1] Due to funding limitations, most schools reduced class size in some early elementary grade levels and not others. For example, a school might reduce class size in grade one but not in kindergarten or grades two or three. This led to a natural experiment where schools reduced class size in some grade levels

[1] In addition to the federal and New York policies analyzed here, class size reduction policies that are targeted at high-needs districts have been enacted by Wisconsin, Tennessee, and the Charlotte-Mecklenberg school district in North Carolina. In Tennessee and North Carolina, the programs were later expanded statewide.

but not others. The policies recommended that, within schools, grades for class size reduction should be determined by grade level and class size.

Using data from the 1999-2000 and 2000-2001 school years, I calculate instrumental variables estimates of the effect of class size on teacher attrition. The primary analyses include school fixed effects to eliminate the effect of unobservable school characteristics on teacher attrition. Therefore, the estimated effect of class size on teacher attrition is based on within-school variation in class size induced by the class size reduction policies. To overcome the possibility that class sizes are assigned based on unobservable teacher or student characteristics, I instrument for class size using the number of teachers districts requested for each grade, in each school, through the class size reduction policies. I also present evidence that districts did not choose grade levels for class size reduction based on factors that would directly affect teacher attrition.

Teachers with smaller classes were not significantly less likely to leave schools in the full sample of districts but were less likely to leave a school in districts that targeted the same grade across schools. Grades were more likely to have continued class size reduction in those districts compared to other districts. For teachers in districts that targeted the same grade across schools, a decrease in class size from 23 to 20 students (a decrease of one standard deviation) decreases the probability that a teacher leaves a school at the end of the year by 4.2 percentage points. This suggests that targeted class size reduction could, in the long run, be used to decrease disparities in teacher turnover and teacher experience across schools. I estimate that the reduction in teacher attrition reduces the cost of class size reduction policies by about three percent.

In the next section, I give background information on related literature and the New York State and federal class size reduction policies. I present the identification strategy in Section 3

and the data in Section 4. The econometric method and results are discussed in Sections 5 and 6. In Section 7 I note cost implications from reduced teacher attrition and conclude.

2. BACKGROUND

Literature Review

There is a well-known literature on the effects of class size reduction on student outcomes. Angrist and Lavy (1999), Krueger (1999), and Rivkin, Hanushek, and Kain (2005) find that smaller class sizes improve student achievement. Hoxby (2000) does not find an effect of class size on student achievement.[2] More recently, Jepsen and Rivkin (2009) find that smaller class sizes resulting from California's 1996 state-wide class size reduction policy improved student achievement, but increases in the share of teachers with no prior experience nor full certification partly offset the student achievement gains due to smaller classes. Other research on California's class size reduction policy has also investigated changes in teacher characteristics (e.g. Bohnstedt and Stecher 2002). In appendix to their report, Bohrnstedt and Stecher (2002) provide some evidence that teachers in small classes have lower attrition rates for schools in the middle of the socioeconomic status (SES) distribution. In these schools, a higher percentage of new teachers leave teaching if they taught large classes in their first one or two years than teachers who taught in small classes both years. They find negligible differences in attrition rates for experienced teachers or teachers in schools in the bottom or top SES quartiles.

Another branch of literature examines the effect of salary and school characteristics on teacher attrition based on cross sectional and longitudinal variation in these variables (e.g. Ondrich, Pas, and Yinger 2008, Gritz and Theobald 1996). Some papers also include classroom

[2] Jepsen and Rivkin (2009, p. 225) note that data problems attenuate the estimates in Hoxby (2000).

characteristics (Hanushek, Kain, and Rivkin 2004, Mont and Rees 1996). This paper focuses on class size and uses a natural experiment to estimate the effect of class size on teacher attrition.

Class Size Reduction Policies in New York State

Both the federal and New York State class size reduction programs began in the 1999-2000 school year.[3] The federal class size reduction program lasted for three school years, from 1999-2000 to 2001-2002. The reauthorization of the Elementary and Secondary Education Act of 2001 (also known as the No Child Left Behind Act) consolidated the program into teacher-quality block grants that could be used for class size reduction or other purposes. In 2007, New York State's Early Grade Class Size Reduction funding was incorporated into State Foundation Aid, used for general operating costs and ongoing programs.[4] I use data on the class size reduction programs for the 1999-2000 and 2000-2001 school years.

Both class size reduction policies aimed to reduce average class size in grades one through three to 20 or fewer students.[5] The New York State policy also targeted kindergarten, and in the second and third years of the federal policy kindergarten was included in that policy as

[3] Bifulco (2001) provides additional information on New York State's policy and its implementation.

[4] 2007 New York State legislation identified districts in need of improvement, including New York City, and mandated development of plans ("Contracts of Excellence") to improve student achievement. Those districts could continue to prioritize class size reduction if they chose.

[5] Officially, the federal policy aimed to reduce class size to 18 or below, but a state goal could be substituted for the federal goal if the state goal was 20 students or less per class and if the state policy was enacted before the federal policy became law. In New York State, the state goal of 20 students per class was also used for the federal policy.

well. Both policies aimed to reduce class size by providing funds to hire additional teachers. Though the policies were targeted at all early elementary grades, due to funding limitations and decisions on how to prioritize funding across schools, most districts requested additional teachers for some but not all of the early elementary grades covered by the policies.[6]

The state and federal policies both targeted districts and schools with the largest class sizes, most disadvantaged students, or lowest performing students. District eligibility for the state program was based on average class size, property and income wealth per pupil, and "extraordinary needs" determined by student poverty, limited English proficiency, and geographic sparsity. Within a district, priority for funds was intended for schools with the lowest levels of academic achievement or the largest class sizes. The state program did not specify how to prioritize low academic achievement and large class sizes, but funds could not be used to reduce class size in low performing schools if class size was already below 20.

Federal funds were distributed to the states and included guidelines on how to distribute funding. Funding was prioritized to districts primarily based on poverty levels, with district total enrollment a secondary consideration. The law did not dictate how a district should distribute funds across schools. A district was not required to spread funding across all elementary schools, but was instead allowed to target funds to schools with the poorest children, worst performance, or largest class sizes.[7, 8] Both the state and federal policies recommended that grades for additional teachers (within schools) be based on average class size in a grade and grade level.

---

[6] Districts may also have limited requests because not all early elementary grades within a school were eligible for class size reduction funds.

[7] Sources for information on the federal program include "Class Size Reduction Program: Guidance for Fiscal Year 2000"

Some districts requested funding for a particular grade in all schools for which class size reduction funding was requested, for example, reducing class size in all first grade classrooms. Table 1 presents the distribution of grades targeted by districts that implemented district-wide policies.[9] District-wide policies were implemented most often for grade one, with more than half of districts implementing district-wide policies in 1999-2000 focusing on grade one. District-wide policies were common: 56 percent of districts in 1999-2000 and 34 percent of districts in 2000-2001 that requested teachers for more than one school implementing district-wide grade

---

(http://www.ed.gov/offices/OESE/ClassSize/Guidance/fy2000guidance.pdf, accessed February 1, 2010), PL 106-113 Section 310 (the law for fiscal year 2000, included in the guidance), and PL 106-554 Section 306 (the law for fiscal year 2001, http://www.ed.gov/offices/OESE/ClassSize/legislation.html, accessed February 1, 2010).

[8] Districts were allowed to request funding from only the federal program, only the state program, or both programs, if they were eligible. However, the federal policy stated that districts must use federal funds to supplement, not replace, funds from state initiatives. The New York State policy also stated that districts must maintain local funds for teacher salaries and benefits, and if districts did decrease local fiscal effort, district class size reduction funds would be decreased in the following year by the same amount.

[9] A district-wide plan refers to all schools for which class size reduction funds were requested, not necessarily all the schools in a district. Not all district policies are only for one grade. For example, a district is counted as having a district-wide policy if teachers were requested for all first grades and some second grades. Both the federal and state policies could contribute to a district-wide plan. District-wide policies are only attributed to districts that requested funding for more than one school.

choice plans. Some districts focused on grade one because they wanted to reduce class size in the earliest grade (U.S. Department of Education 2004). Other districts focused on grade three to focus on students in the year prior to fourth grade standardized tests.

Though the New York State and federal class size reduction policies targeted relatively disadvantaged students, the policies were fairly widespread. Table 2 presents information on the share of districts and schools that requested funding through the class size reduction programs, excluding New York City. Many districts requesting state funding also requested federal funding. More than 40 percent of schools were funded in 1999-2000 and 2000-01.[10]

Consistent with the intent of the programs, schools that requested class size reduction funding had a higher percentage of students eligible for free or reduced price lunches. Schools requesting funding were also characterized by 1) larger class sizes in 1998-99, before the policy started, 2) a larger proportion of minority students, and 3) a lower levels of academic performance in 1998-99, measured by the percent of students scoring in the lowest two levels on the New York State English Language Arts and Mathematics tests. Table 3 shows the extent to which the characteristics of targeted schools differ from non-targeted schools. Since the schools requesting funding differed between 1999-2000 and 2000-01, characteristics of schools for both years are presented.

3. IDENTIFICATION STRATEGY

Endogeneity of Class Size

To estimate the causal effect of class size on teacher retention, it is necessary to separate the effect of class size on retention from unobservable district, school, or student characteristics that are correlated with class size. For example, in New York State a significant portion of school

[10] Data used to create Tables 1, 2, and 3 is discussed in detail in Section 4.

funding depends on local property taxes, so a district with greater property wealth or higher tax rates can afford smaller classes, but these districts may be desirable places to teach for other reasons as well. State and federal education aid also contribute to the financial resources of districts. Variation in class size within a district is related to observed and unobserved school characteristics. In this New York State elementary school data, 31 percent of class size variation across schools is across schools within districts. This could be due to enrollment fluctuations, compensatory policies such as the federal Title 1 program that directs funds to schools based on poverty rates, or decisions by the district on how to distribute revenues across schools (Steifel, Rubenstein, and Schwartz 2004).

Within an elementary school, variation in class size across years could be due to annual enrollment fluctuations and variation in class size across teachers could result from remedial classes or a school principal purposely assigning teachers or students to smaller or larger classes. In a model of optimal class size, Lazear (2001) argues that schools should place better behaved students in larger classes and more disruptive students in smaller classes, but Dills and Mulholland (2006) find no support for this hypothesis for third grade students in public schools. They do find, however, that public schools place higher achieving students in slightly larger classes. Player (2006) speculates that schools may reward teachers of higher quality with smaller classes, but found no evidence of that in analyses using North Carolina data on elementary school teachers. In the New York data, the median difference in class size between the smallest

and largest class in each grade is only 2 students, suggesting little variation of class size between classes within a grade.[11]

An Instrumental Variable for Endogenous Class Size

To address all sources of class size endogeneity, I instrument for class size using the number of teachers the district requested for each school grade level and employ school fixed effects to account for differences in working conditions and student characteristics across schools. Therefore, the estimate of the effect of class size on teacher attrition is based on variation in class size across grades within schools. The variation in class size across grades is induced by the federal and state class size reduction policies. The instrumental variable (IV) addresses any correlation between class size and unobserved student or teacher characteristics that affect teacher attrition from a particular school.

In addition, because the instrumental variable is based on a policy choice, it incorporates differences in class size that teachers may believe to be long term. Teachers are more likely to view class size differences within schools that arise due to enrollment fluctuations as transient, while seeing differences in class size due to a policy change as long term. Consistent with models of employment decisions that incorporate expected life cycle earnings and promotion opportunities (Brewer 1996), teachers may value long term changes more than transient changes.

Validity of Instrument

For the number of class size reduction teachers requested to be a valid instrument for class size, it must meet two criteria: (1) it must, conditional on all other variables, predict class

[11] If the number of students is not divisible by the number of classes, then the difference between the largest and smallest classes must be at least one. Unintentional differences in class size could also result from students withdrawing from the school.

size and, (2) it must not be correlated with omitted grade, student cohort, or teacher characteristics that would directly affect teacher attrition. On the first condition, first stage regression results show that the number of teachers requested by the district strongly predicts a teacher's class size. In analyses with school fixed effects the t-statistics on the number of teachers requested have absolute values of 5.8 (for the full sample of districts) and 14.2 (for the subsample of districts with district-wide policies). These results suggest that districts received class size reduction funds in time to hire additional teachers and schools were able to fill positions created by the class size reduction funds. In addition, there were not widespread limitations in the amount of space available for additional classrooms that prohibited smaller classes from forming.[12] This also suggests that, in general, districts chose not to reduce class sizes for all early elementary grades; instead they focused class size reduction on grades for which they received class size reduction funds.

On the second condition for a valid IV, there is evidence to suggest that the grades chosen for class size reduction were not correlated with omitted grade, student cohort, or teacher characteristics that would directly affect teacher attrition. Although teacher requests at the school or district level may have been correlated with teacher attrition since the policies targeted schools with difficult working conditions, there is no evidence that grade choice *within schools* was related to factors that affected teacher attrition.

[12] Neither program provided funding for facilities that would enable schools or districts to overcome serious space shortages. The federal law did not provide any funding for facilities. The New York State program provided some funding for facilities, although the funds cannot be used for new buildings or additions. U.S. Department of Education (2004) discusses difficulties some districts faced in implementing the federal class size reduction program.

For districts that implemented district-wide policies, grade choice was not made on the basis of school-specific factors that would directly affect teacher attrition. District-wide policies were common (56 percent of districts that requested funding for more than one school in 1999-2000 and 34 percent of districts in 2000-2001; see Table 1).

Districts did not appear to make funding requests based on information about student cohorts, such as academic ability or the number of disruptive students. The school data lack grade level student information, but I test whether teacher attrition differed systematically by student cohorts for which funding was requested. For the full sample of districts, I examine whether teachers were more likely to leave teaching if they taught a cohort of students targeted for class size reduction in a non-policy year. For example, if additional teachers were requested for second grade in a school in 1999-2000, I test whether teachers of first grade students in 1998-1999 were more likely to leave teaching than teachers in other grades. In this example, if the school did not request class size reduction funding in 2000-2001, I would also look at third grade students in 2000-2001. The coefficient on cohort is not significantly different from zero (p-value=0.50).[13] Using a similar approach, I examine whether there are unobserved grade level factors affecting teacher attrition systematically related to grades chosen for class size reduction. I find that teachers assigned to grades chosen for class size reduction in non-policy years are no

[13] The sample includes schools from the 1997-1998 school year to the 2000-2001 school year and excludes school-years with class size reduction funding. The model is a linear probability model with the dependent variable equal to one if a teacher exited a school at the end of the year. The model controls for teaching a cohort of class size reduction students, teacher characteristics, and school fixed effects. Teachers in their first year at a school are excluded.

more or less likely to leave teaching than teachers in other grades. The coefficient on grade in the model is not significantly different from zero (p-value=0.38).[14]

I find minimal evidence that districts chose grades based on teacher characteristics. I examine whether there was a systematic relationship between grades chosen for class size reduction and three observable teacher characteristics: passing the certification test on the first try, years of experience, and attending a top tier college. I look at the year before the class size reduction policies were implemented, since that is when requests for funding were made. If grade choice were not based on observed teacher characteristics, that would provide suggestive evidence that districts were not making grade choice decisions based on unobserved teacher attributes. I regress teacher characteristics on an indicator variable equal to one if a teacher taught in a class size reduction grade.[15]

In some specifications, passing the certification exam on the first attempt is a statistically significantly predictor of grade choice and grades where teachers had failed the certification test on the first attempt were more likely to be chosen for class size reduction. Passing the certification test was not significant for all school using class size reduction schools in the 1999-

[14] The sample and model are the same as the cohort analyses except that an indicator for teaching a grade of class size reduction students is included instead a cohort indicator.

[15] Analyses included teachers in the 1998-1999 school year who taught in class size reduction schools in the 1999-2000 school year. Teacher characteristics were regressed on whether the teachers taught in class size reduction grades in the 1999-2000 school year using a linear probability model with school fixed effects. Additional analyses included teachers for the 1998-1999 and 1999-2000 school years who taught in class size reduction schools in the 1999-2000 school year or newly funded schools in the 2000-2001 school year.

2000 school year and newly funded schools in the 2000-2001 school year; that variable was significant at the 10 percent level for schools in districts with district-wide policies for those years. Passing the certification test was significant at the five percent level using data from the first year of the policy for all schools and schools in districts with district-wide policies.[16] There is no evidence in these data, however, that teachers who passed their certification test on the first attempt are more or less likely to leave teaching.

Other teacher characteristics, including teacher experience and whether a teacher attended a top tier college, were not systematically related to grades chosen for class size reduction. For the subset of districts with district-wide policies, results are very similar to those for the full sample for the student cohort, grade level, and teacher characteristic tests.

Finally, I confirm that there were no statewide policies coordinated with class size reduction and none of the districts I spoke with implemented coordinated district policies. In sum, there is little evidence to suggest districts or schools chose which grade to target for class size reduction based on factors that would directly affect teacher attrition, supporting the validity of the instrumental variable.

4. DATA

I rely on extensive data from the New York State Education Department for the 1997-98 to 2000-01 school years. The Personnel Master File contains annual survey data from all public school teachers in New York State and has information on personal characteristics and working conditions, including grade taught, class size, and salary. Using individual teachers' salary, education, and experience, I estimate the starting salary in each district. The estimated started

[16] Certification test information is consistently available only for teachers who have been teaching for less than about 14 years.

salary is in 2001 dollars. I use this district-level estimate instead of each teacher's salary, since it better reflects the full salary schedule in a district, thereby proxying teacher expectations of future earnings. I merge these data to the New York State Teacher Certification Database, which documents the number of attempts made by a teacher before passing the state certification exam and the college a teacher attended. The colleges are matched to U.S. News and World Report college rankings to determine whether the teacher attended a top tier college.[17]

I merge school characteristics from the Institutional Master File, which is compiled from surveys of school administrators and comprises data on enrollment, student characteristics, and race and ethnicity of teaching staff. This data set also contains school zip code information that I use to create nine region variables based on local teacher labor markets.[18] Finally, I merge school-level student performance in fourth grade math and English language arts from school report card data. Student performance is measured by the percent of students in each of four performance levels or mean test scores.[19]

I also use data on the number of additional teachers requested by the district for each school and grade through the class size reduction policies. These data are based on requests for

[17] I define top tier as a tier one or two college or university, based on rankings available June 2001. For example, Barnard College is tier one, and State University of New York at Binghamton is tier two.

[18] The regions are Buffalo region, Rochester region, Syracuse region, Southern tier, Albany region, North country, mid-Hudson region, Utica-Rome region, and New York City region. These are the same regions used by Lankford, Loeb, and Wyckoff (2002).

[19] The lowest level, level one, means that students have "serious academic deficiencies." Level two means that "students need extra help to meet the standards and pass the Regents exam."

funding written by the districts. I have information for the 1999-2000 and 2000-2001 school years. I limit my analysis to grades kindergarten to three because the policies were targeted at these grades, and these are the only grades for which grade level information is available.

Some schools and classes are excluded from the analyses. Because New York City data do not include grade level information, New York City teachers are excluded. Second, New York State relies on the fourth grade tests for identifying the lowest performing schools (Schools Under Registration Review, or SURR). Teaching in a school marked as a SURR may affect teacher morale or otherwise affect the working environment, and restructuring efforts or school closures at SURR may cause teachers to leave involuntarily. The six upstate SURR that received class size reduction funds are excluded. Third, remedial classes are excluded since they tend to be smaller and have distinct students (Boozer and Rouse 2001, Akerhielm 1995). Finally, some districts have missing data for a year and those district-years are also excluded.

5. MODEL

I estimate the probability a teacher will continue teaching in the same school as a function of class size, teacher characteristics, school characteristics, and district characteristics:

$$y_i = f\left(\ln(n_i), \mathbf{X}_i, \boldsymbol{\gamma}_s, \lambda_{gs}\right) \qquad (1)$$

where y_i equals 1 if teacher *i* exits school *s*, n_i is teacher *i*'s class size, $\mathbf{X}_i$ is a vector of teacher characteristics, $\boldsymbol{\gamma}_s$ is a vector of school fixed effects, and λ_{gs} indicates if a grade *g* in school *s* loses class size reduction funding in the following year.[20] I estimate linear probability models (LPM) and probit models for comparison. Standard errors in the LPM and the probit are adjusted

[20] For teachers who teach in more than one class or school, the class size variable is the average class size of a teacher in their modal school.

for heteroskedasticity using the Huber-White method and are clustered at the school level.[21] Clustering of standard errors at the school level also allows error terms for teachers who stay in the same school for both years to be correlated, although the error terms for an individual teacher will not necessarily be the same for each year. An exit is defined as a teacher not teaching in the same school in the following year. A teacher could have transferred to another school, left teaching altogether, or moved out of state. In the probit model and some specifications of the linear probability model school fixed effects are not included and a vector of school characteristics, $\mathbf{X}_s$, and a vector of district characteristics, $\mathbf{X}_d$, are included instead.

I control for a variety of teacher characteristics that affect attrition, including gender, whether a teacher had an advanced degree (Master's or Ph.D.), certification status (provisional or permanent), and years of teaching experience (zero to two years, three to five years, six to ten years, or more than ten years experience). As a specification check, additional analyses include variables for whether a teacher graduated from a top-tier college and whether a teacher passed the certification test on the first attempt. These variables are not included in all analyses due to substantial missing data. I specify the class size variable as the logarithm of class size since one additional student will have a smaller effect on the classroom environment as class size expands.

In models that do not use fixed effects, school characteristics include the percent of students eligible for free or reduced price lunches, the percent black students, and the percent Hispanic students. District characteristics include predicted starting salary and region dummy variables.

[21] Standard errors in the LPM need to be adjusted for heteroskedasticity since the dependent variable is binary.

Changes in teacher demand may have affected the teacher attrition analyses if class size reductions were not continuously funded. If a school-grade had funding requested in one year and not the following year, the number of teachers may decrease from the year with reduced class size to the next year, and smaller class sizes would seem to cause *higher* teacher attrition. Therefore I use only 1999-2000 data and include a variable indicating grades that lost class size reduction funding in the following year. For the district-wide sample, I also do analyses with both years of data without the loss of funding variable. I exclude newly hired teachers from the analyses. Newly hired teachers have the least seniority, and are disproportionately more likely to leave a school if a school-grade does not request funding in the following year. In addition, other analyses suggest that the class size reduction policies altered the composition of new faculty. These newly hired teachers may have different propensities for attrition.

Both the linear probability model and the probit can be extended to address class size endogeneity by replacing the natural log of class size, $\ln(n_i)$, with the predicted natural log of class size, $\hat{\ln}(n_i)$:

$$\hat{\ln}(n_i) = \alpha_1 Z_{gs} + \mathbf{X}_i\alpha_2 + \boldsymbol{\gamma}_s\alpha_3 + \alpha_4\lambda_{gs} + \nu_i . \qquad (2)$$

Class size is a function of Z_{gs}, the number of teachers requested through the class size reduction policies at the school-grade level, teacher characteristics, school fixed effects (or school and district characteristics), and whether a grade lost class size reduction funding in the following year. The instrumental variable is the number of teachers requested for each grade.

I estimate equations (1) and (2) with two-stage least squares. Like the LPM, standard errors are adjusted for heteroskedasticity using the Huber-White method and are clustered at the school level. As robustness tests of these results, I include results from (1) a two-stage least square model that incorporates school and district characteristics in place of school fixed effects,

and (2) an instrumental variables probit model estimated with conditional maximum likelihood. This method has coefficient estimates that are straightforward to interpret and permits clustering of standard errors. In the probit model, school and district characteristics are included instead of school fixed effects, and standard errors are clustered at the school level and are adjusted for heteroskedasticity using the Huber-White method.

6. RESULTS

Table 4 presents summary statistics for the data used in analyses. About 10 percent of teachers leave the school at the end of the school year in the full district sample. In the full district sample, one class size reduction teacher was requested for about one in four grades. More additional teachers were requested in the districts with district-wide policies; one teacher was requested for about 4 out of 10 grades. The average class size is between 20 and 21 students.

Table 5 presents results for the class size coefficient. The class size variable is the natural logarithm of class size, so the coefficient is interpreted as the percentage point increase in the likelihood of a teacher leaving a school resulting from a one percent increase in class size. Results are presented for three models: a linear probability model with school fixed effects, a linear probability model with school and district characteristics in place of school fixed effects, and a probit with school and district covariates. Probit coefficients (with and without instrumental variables) are presented as marginal effects calculated at the means of the continuous independent variables or for a change from 0 to 1 for the discrete variables.

The class size coefficient is statistically insignificant for the full set of districts for 1999-2000 in LPM models or standard probit models, as shown in Panel A. Inclusion of an instrument does not change the basic results when all districts are included in the analysis.[22]

Panel B shows results for the sub-sample of district-years where there are district-wide class size reduction policies; both 1999-2000 and 2000-2001 are included and specifications do not include a variable indicating loss of funding. The LPM and standard probit coefficient estimates on class size are not statistically significant. The IV results, however, which correct for the endogeneity of class size, are positive and statistically significant at the five percent level in all specifications. Results are similar for districts-years with district-wide policies using only the 1999-2000 school year and including the loss of funding variable (results not presented). However, using only 1999-2000 approximately halves the number of observations, increases the standard errors, and produces statistically insignificant coefficient estimates.

Based on the LPM coefficient estimate of 0.298 in the IV model with school fixed effects, a 1 percent increase in class size leads to a 0.00298 increase in the probability a teacher leaves the school, or equivalently, a 1 percent decrease in class size leads to a 0.00298 decrease in the probability a teacher leaves the school. Based on this estimate, a decrease in class size from 23 to 20 students—from one standard deviation above the mean to the mean class size—will decrease the probability a teacher leaves a school by 4.2 percentage points. This is a substantial effect since the average attrition rate prior to the class size reduction policy was 10 percent.

[22] A model that uses both years of data and excludes the loss of funding variable also produces class size coefficient estimates that are statistically insignificant.

Results using district-wide policies are robust to changes in the specification. Results are similar using linear class size instead of the natural logarithm of class size, or clustering standard errors at the school-grade level instead of at the school level. Using alternate groups of school and district variables produces similar results, including using alternate measures of socioeconomic status and adding student achievement measures. Inclusion of whether a teacher passed the certification exam on the first attempt leads to similar results.

One might be concerned that schools may have transferred teachers across grades within schools during the class size reduction policies. To examine whether transfers across grades affect the results, I do additional analyses excluding teachers who transferred across grades. Class size results are similar and remain statistically significant.

Finally, I test whether class size has differential effects on teachers with different experience levels, i.e. class size is interacted with the teacher experience variables. There are no consistent differential effects of class size.

The differences in results between the IV model in Panel B and the other results are likely due to teacher expectations. Temporary fluctuations in class size due to enrollment or adjustments for student characteristics may not affect teacher attrition, while changes in class size that are expected to be long term may. Teachers in grades targeted for class size reduction in districts with district-wide policies may have expected the class size reduction policy to continue while teachers in other districts did not. This is consistent with the way the class size reduction policies were implemented. Loss of funding is more prevalent in the full sample of districts than in districts with district-wide policies. Forty-seven percent of school-grade requests in 1999-2000 did not have subsequent requests in 2000-2001 for the full district sample, compared to 40 percent of school-grades in the district-wide sample. In schools with district-wide policies,

grades that were part of the district-wide policies were more likely to keep class size reduction funding than grades that were not.[23] The results may also have differed across samples due to the fact that requests for additional teachers was a much stronger predictor of class size for schools in districts with district-wide policies.

7. DISCUSSION

Using instrumental variable estimates based on class size reduction policies, I find that reducing class size reduces teacher attrition in districts with district-wide grade choice for class size reduction policies. These results are robust in a wide range of specifications. A decrease in class size from 23 to 20 students decreases the probability a teacher leaves the school by 4.2 percentage points. For the full sample of districts, class size is not significantly related to teacher attrition. The results suggest that teachers may have expected the policy to continue longer and valued future expected small class sizes in districts with district-wide policies, since grades for class size reduction were more likely to continue having reduced class sizes in those districts.

The class size reduction policies in New York State led to reduced teacher attrition in some districts, suggesting that the cost of class size reduction was partially offset by reduced turnover costs.[24] Turnover costs, including separation costs (like exit interviews), hiring costs, and training costs, have been estimated as around $4,388 in 2001 dollars per teacher (Texas

[23] Schools in districts with district-wide policies have a slightly higher percentage of minority students than other districts, but there is no evidence class size has a differential effect on schools with more minority students. When class size was interacted with the percent black students or percent Hispanic students in the full district sample, the interaction is not statistically significant.

[24] Although due to the funding structure of the program, districts likely saved on turnover costs, while the state and federal governments bore the cost of hiring additional teachers.

Center for Educational Research 2000).[25] I do a back-of-the-envelope calculation to determine how much reduced teacher attrition offsets the cost of class size reduction. Assume that 100 teachers each teach classes of 23 students. To reduce class size to 20 students, 15 new teachers are hired at the average starting salary of $34,396 (see Table 4). Salary averages 69.1 percent of total compensation for employees in elementary and secondary schools, so total compensation cost, including benefits (health insurance, paid leave, etc.), is $49,777 per teacher.[26] Therefore, the cost to hire 15 teachers is $746,657. The class size reduction policy decreases the probability of all 115 teachers leaving teaching by 4.2 percentage points, resulting in 4.8 fewer teachers leaving teaching.[27] (I permit fractional teachers in this exercise.) Reducing attrition by this amount leads to savings in turnover costs of $21,194, for a savings rate of 2.8 percent. This calculation excludes administrative costs associated with hiring new teachers under a class size

[25] Two districts in Texas report complete information on the cost of replacing a teacher. The districts reported costs of $5,166 and $3,367. I use the average of $4,266 in 2000 dollars and convert to 2001 dollars, equaling $4,388.

[26] Salary and benefits shares of total compensation are based on Bureau of Labor Statistics (BLS) calculations from the National Compensation Survey. Statistics on employees in elementary and secondary schools are in Table 2 of a December 9, 2009 BLS Employer Costs of Employee Compensation news release: http://www.bls.gov/news.release/pdf/ecec.pdf (accessed February 1, 2010).

[27] This cost analysis assumes that new hires are less likely to leave a school if they have smaller classes. New hires were excluded from the attrition analyses primarily because they were disproportionately more likely to leave a school if the class size reduction policy was discontinued.

reduction program. The estimated savings rate of 2.8 percent would be applicable for years after the initial implementation.

A comparable calculation shows that using salary increases may cost less than class size reduction for an equivalent decrease in teacher attrition. Clotfelter et al. (2008) find that bonuses of $1,800, about four percent of base salary on average, reduce the teacher turnover rate by 17 percent. Extrapolating from this estimate, a salary increase of 9.9 percent would be necessary for a reduction in teacher attrition of 42 percent, which is equivalent to the expected effect of a decrease in class size from 23 to 20 students (a 4.2 percentage point reduction from a base attrition rate of 10 percent). (In this calculation, I assume that Clotfelter et al.'s (2008) estimate of the effect of bonuses also applies to salary increases.) For 100 teachers earning the median salary of $54,410 in class size reduction districts, increasing salaries by 9.9 percent would cost $5,387 per teacher on average, for a total of $538,659. This is 28 percent less than the cost of reducing teacher attrition through a comparable class size reduction policy. The difference in costs in entirely due to the cost of benefits for the additional teachers hired through the class size reduction policy. Without the cost of benefits, salary increases cost four percent more than the comparable class size reduction policy. A policy of increasing salaries would be more substantially more expensive if the effect of salary on retention was closer to estimates found in Hanushek, Kain, and Rivkin (2004).

In conclusion, teachers show that they value small class sizes because they are less likely to leave a school when they have smaller classes. However, it appears that teachers must view the policy as a long-term change for class size reduction to affect teacher behavior. In the short run, class size reduction increases the share of inexperienced teachers (Jepsen and Rivkin 2009, Bifulco 2001, Pas 2007), but in the long run reducing class size may retain experienced teachers

in schools with disadvantaged students. This, in turn, can improve student achievement through both the direct effect of smaller classes on student achievement and the indirect effects of decreasing the fraction of beginning teachers in the classroom and decreasing the disruption associated with teacher turnover.

References

Angrist, Joshua D. and Victor Lavy. 1999. "Using Maimonides' Rule to Estimate the Effect of Class Size on Scholastic Achievement." *Quarterly Journal of Economics* 114(2) (May): 533-75.

Akerhielm, Karen. 1995. "Does Class Size Matter?" *Economics of Education Review* 14(3) (September): 229-24.

Bifulco, Robert. 2001. *The Impact of the New York State Class Size Reduction Initiative on Teacher Resources*. Report commissioned by and submitted to the New York State Education Department. May.

Bohrnstedt, George W. and Brian M. Stecher, eds. 2002. *What We Have Learned About Class Size Reduction in California*. California Department of Education, Sacramento, California.

Boozer, Michael and Cecilia Rouse. 2001. "Intraschool Variation in Class Size: Patterns and Implications." *Journal of Urban Economics* 50: 163-189.

Brewer, Dominic. 1996. "Career Paths and Quit Decisions." *Journal of Labor Economics* 14(2): 313-339.

Clotfelter, Charles, Elizabeth Glennie, Helen Ladd, and Jacob Vigdor. 2008. "Would Higher Salaries Keep Teachers in High-Poverty Schools? Evidence from a Policy Intervention in North Carolina." *Journal of Public Economics* 92(5/6) (June): 1352-1370.

Dills, Angela K. and Sean E. Mulholland. 2006. "The Peculiarities of Public and Private Production: Within School Sorting of Pupils." Working Paper.

Ferguson, Ronald F. and Helen Ladd. 1996. "How and Why Money Matters: An Analysis of Alabama Schools," in Ladd, H.F. (Ed.), *Holding Schools Accountable*. Washington, D.C.: Brooking Institution Press.

Gritz, R. Mark, and Neil D. Theobald. 1996. “The Effects of School District Spending Priorities on Length of Stay in Teaching.” *The Journal of Human Resources* 31(3): 477-512.

Hanushek, Eric A., John F. Kain, and Steven G. Rivkin. 2004. “Why Public Schools Lose Teachers.” *The Journal of Human Resources* 39(2) (Spring): 326-54.

Hoxby, Caroline M. 2000. “The Effects of Class Size on Student Achievement: New Evidence from Population Variation.” *The Quarterly Journal of Economics* 115(4) (November): 1239-1285.

Krueger, Alan B. 1999. “Experimental Estimates of Education Production Functions.” *Quarterly Journal of Economics* 114(2) (May): 497-532.

Jepsen, Christopher and Steven Rivkin. 2009. “Class Size Reduction and Student Achievement: The Potential Tradeoff Between Teacher Quality and Class Size.” *The Journal of Human Resources* 44(1) (Winter): 223-250.

Lankford, Hamilton, Susanna Loeb, and James Wyckoff. 2002. “Teacher Sorting and the Plight of Urban Schools: A Descriptive Analysis.” *Educational Evaluation and Policy Analysis* 24(1) (Spring): 37-62.

Lazear, Edward P. 2001. “Educational Production.” *The Quarterly Journal of Economics* 116(3) (August): 777-803.

Mont, Daniel, and Daniel I. Rees. 1996. “The Influence of Classroom Characteristics on Teacher Turnover.” *Economic Inquiry* 34(1) (January): 152-167.

Ondrich, Jan, Emily Pas, and John Yinger. 2008. “The Determinants of Teacher Attrition in Upstate New York.” *Public Finance Review* 36(1) (January): 112-144.

Pas, Emily. 2007. “Essays on Teacher Labor Markets and Educational Disparities.” Dissertation, Syracuse University.

Player, Daniel. 2007. “Non-Monetary Returns to Teacher Quality.” Working Paper.

Rivkin, Steven G., Eric A. Hanushek, and John F. Kain. 2005. “Teachers, Schools, and Academic Achievement.” *Econometrica* 73(2): 417-58.

Steifel, Leanna, Ross Rubenstein, and Amy Ellen Schwartz. 2004. “From Districts to Schools: The Distribution of Resources Across Schools in Big City School Districts.” Paper presented at the Symposium on Education Finance and Organizational Structure in New York State Schools, March 4, in Albany, NY.

Stinebrickner, Todd R. 1999. “Estimation of a Duration Model in the Presence of Missing Data.” *The Review of Economics and Statistics* 81(3) (August): 529-542.

Texas Center for Educational Research. 2000. *The Cost of Teacher Turnover*. Report prepared for the Texas State Board for Educator Certification.

U.S. Department of Education, Office of the Deputy Secretary, Policy and Programs Studies Service. 2004. *A Descriptive Evaluation of the Federal Class-Size Reduction Program: Final Report*, Doc. Number 2004-18, by Mary Ann Millsap, Jennifer Giancola, W. Carter Smith, Dana Hunt, Daniel C. Humphrey, Marjorie E. Wechsler, and Lori M. Reihl.

Table 1: Grades Chosen for District-Wide Class Size Reduction Policies

	1999-2000		2000-2001	
	Number of Districts	Percent of District-Wide Policies	Number of Districts	Percent of District-Wide Policies
Districts requesting funding	426		478	
Districts requesting funding for more than one school	135		152	
Districts with district-wide policies	76		52	
All kindergarten	3	3.9	5	9.6
All grade 1	41	53.9	23	44.2
All grade 2	23	30.3	18	34.6
All grade 3	19	25.0	15	28.8

NOTE: Excluding New York City. All grade percents may sum to more than 100, since districts may request funding for all grades for more than one grade, for example requesting funding for all first and second grades.

Table 2: Extent of Class Size Reduction Policies

	1999-2000	2000-2001
Districts		
Total number of districts (with grade 1-3 schools)	685	684
Requested funding from federal policy	403	448
Requested funded funding from state policy	95	155
Requested funding from both policies	72	125
Total number of districts requesting funding	426	478
Percent of districts requesting funding	62.2%	69.9%
Schools		
Total number of schools with enrollment in grades 1-3	1,798	1,801
Requested funding from federal policy	664	738
Requested funded funding from state policy	186	352
Requested funding from both policies	100	196
Total number of schools requesting funding	750	894
Percent of schools requesting funding	41.7%	49.6%

NOTE: Excluding New York City. Some districts are missing federal or state data, so the numbers presented here may be underestimates.

Table 3: Characteristics of Funded and Not Funded Schools

	1999-2000		2000-2001	
	Requested Funding	Did Not Request Funding	Requested Funding	Did Not Request Funding
Percent of students				
Eligible for free or reduced price lunch	34.6%	28.0%	36.8%	27.0%
Black	11.2%	9.5%	13.9%	9.8%
Hispanic	8.0%	5.3%	8.0%	5.8%
Percent of students scoring in the lowest 2 test score levels in 1998				
English Language Arts	45%	40%	46%	40%
Math	24%	20%	25%	20%
Average class sizes in 1998				
Kindergarten	20.4	20.1	20.6	20.0
Grade 1	21.1	20.2	21.1	20.2
Grade 2	21.6	20.9	21.7	20.7
Grade 3	22.4	21.5	22.3	21.6

NOTE: Excluding New York City. Average class sizes is defined as the average of average class size for each grade for academic subjects. The number of schools in each sample varies. Means for schools that requested funding and schools that did not request funding are statistically significantly different at the 5 percent level, except percent black students in 1999-2000 and kindergarten class size in 1999-2000, which are statistically significantly different at the 10 percent level.

Table 4: Summary Statistics for Teacher Attrition Analyses

	Full District Sample, 1999-2000				District-Wide Sample, 1999-2000 and 2000-20001			
Variable	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Teacher exits school	0.10	0.31	0	1	0.11	0.31	0	1
CSR Policy variables								
Number of class size reduction teachers requested	0.27	0.51	0.0	4.0	0.40	0.62	0.0	4.5
Grade loses funding	0.12	0.33	0	1	--	--	--	--
Teacher characteristics								
Natural log of class size	3.00	0.17	1.79	3.61	3.02	0.17	1.95	3.69
Class size	20.26	3.20	6	37	20.83	3.33	7	40
Male	0.04	0.21	0	1	0.05	0.21	0	1
Advanced Degree	0.75	0.43	0	1	0.78	0.41	0	1
Regular Certification	0.99	0.11	0	1	0.99	0.09	0	1
0-2 years teaching experience	0.06	0.24	0	1	0.08	0.27	0	1
3-5 years teaching experience	0.11	0.31	0	1	0.13	0.34	0	1
6-10 years teaching experience	0.16	0.37	0	1	0.18	0.39	0	1
11 or more years teaching Experience	0.67	0.47	0	1	0.61	0.49	0	1
School characteristics								
Percent students eligible for free or reduced price lunch	0.30	0.22	0.00	1.00	0.31	0.24	0.00	1.00
Percent black students	0.09	0.16	0.00	0.98	0.13	0.17	0.00	0.90
Percent Hispanic students	0.06	0.10	0.00	0.79	0.10	0.15	0.00	0.62
District characteristics								
Natural log of district starting salary	10.44	0.13	9.93	10.90	10.49	0.11	10.16	10.73
District starting salary	34,396	4,528	20,554	54,157	36,029	3,932	25,934	45,926
Buffalo region	0.09	0.28	0	1	0.07	0.26	0	1
Rochester region	0.07	0.25	0	1	0.05	0.22	0	1
Syracuse region	0.07	0.25	0	1	0.06	0.24	0	1
Southern Tier region	0.12	0.32	0	1	0.06	0.23	0	1
Albany-Schenectady-Troy region	0.09	0.28	0	1	0.08	0.27	0	1
North Country region	0.08	0.27	0	1	0.03	0.18	0	1
Mid-Hudson region	0.11	0.31	0	1	0.08	0.28	0	1
Utica region	0.05	0.22	0	1	0.02	0.15	0	1
New York City region	0.33	0.47	0	1	0.54	0.50	0	1
Observations (in teacher-years)	9,175				4,394			

NOTE: New York City is excluded; other districts in the New York City region are included. Grade loses funding statistics are based on all grades, not just class size reduction grades.

Table 5: Class Size Coefficient Estimates, Teacher Attrition Analyses

Panel A: Attrition results for full sample of districts, 1999-2000		
	Without IV	With IV
Linear probability model with school FE	0.020	0.392
	(0.023)	(0.366)
Linear probability model without school FE	0.029	0.421
	(0.022)	(0.326)
Probit	0.027	0.458
	(0.022)	(0.406)
Observations (in teacher-years)	9,175	9,175
Panel B: Attrition results for sample of districts with district-wide policies, 1999-2000 and 2000-2001		
	Without IV	With IV
Linear probability model with school FE	0.012	0.298**
	(0.036)	(0.142)
Linear probability model without school FE	0.027	0.729**
	(0.031)	(0.318)
Probit	0.027	0.879**
	(0.031)	(0.416)
Observations (teachers)	4,394	4,394

NOTE: Standard errors in parentheses. Standard errors are clustered at the school level. Coefficient estimates and standard errors for the instrumental variables probit model were obtained using conditional maximum likelihood estimation. Probit and IV probit coefficients are marginal effects. * indicates significance at the 10 percent level, ** at the 5 percent level, and *** at the one percent level.