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The Design of Bonus Schemes and Their Impact on Teacher Recruitment and Retention: The Case of Georgia's Bonus Program for Early-Career Math and Science Teachers*

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Traditionally, teacher salaries have been determined solely by experience and educational attainment. This has led to chronic shortages of teachers in particular subject areas, such as math, science, and special education. There is a small literature which finds that bonuses and loan forgiveness can ameliorate subject-specific teacher shortages by substantially increasing retention of teachers in such "high-need" subjects. In contrast to prior work, we find that Georgia's bonus system for early-career math and science teachers has not increased teacher retention in these subject areas. The lack of efficacy can be traced to four key elements of the design and implementation of Georgia's bonus system: uncertainty in program funding, ex-post payments that are not conditional on future employment, an eligibility cap based on years of experience, and poor communication about the program to teachers. Our findings demonstrate the need to carefully design and implement bonus systems to achieve the potential benefits of differential pay structures.

Keywords: STEM teacher shortages, teacher bonus pay, teacher recruitment and retention

JEL codes: I21, I28, J20

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I. Introduction

The United States has a chronic shortage of qualified teachers in hard to staff subjects-such as math, science and special education -areas that are key to long run economic growth[3]. This chronic shortage, coupled with the finding that teachers are the most influential input to student success (e.g. Chetty, Friedman, and Rockoff 2014), begs the question does paying higher salary to hard-to-staff-subject teachers increase the supply and retention of these teachers? This question has been difficult to answer due to few states implementing such a policy and being able to collect the necessary data. Traditionally, states pay public-school teachers have been paid equally according to fixed salary schedules, with wages determined solely by years of experience and educational attainment. Given variation in the opportunity cost of teachers and in the non-pecuniary characteristics of their jobs, the use of fixed salary schedules has produced chronic shortages of teachers in particular subject areas.

In this paper we study the design of Georgia's statewide salary differential program and its effects on teacher retention and the supply of new teachers. We focus on differential pay by subject, i.e. monetary compensation that is based on the subject area a teacher is trained and teaches in. Unlike Georgia, most salary differentials are operated at the district level (Martin, 2007). We use a difference-in-difference identification strategy to determine if implementing a subject-specific bonus for early career teachers impacts their labor market decisions to enter the teacher labor market and remain in it. We find that implementation of differential pay for math and science

[3] Ingersoll and Perda (2009) find that roughly 3 to 4 times as many secondary schools report significant difficulty in filling positions in mathematics, special education and science relative to English or social studies. Cowan, Goldhaber, Hayes, and Theobald (2016) note that the proportion of schools across the U.S. reporting difficulty in filling special education (SPED) and science, technology, engineering, and math (STEM) vacancies far exceeded that in other subject areas throughout the period 1990-91 to 2011-12. McVey and Trinidad (2019) report that SPED, science, mathematics, and foreign language are consistently hard-to-staff subjects in the U.S. See Goldhaber, Krieg, Brown, and Theobald (2015) and James, Kraft, and Papay (2023) for difficulty of retaining subject-specific teachers at the local level.

teachers in grades 6-12 did not attract new teachers nor did it increase retention for existing teachers who received the bonus. We argue that this lack of efficacy is due to the design of the differential system in Georgia and highlight the importance of the design and implementation of pay systems to address subject-specific teacher shortages.

The shortage of qualified teachers in hard-to-staff subjects can lead to adverse outcomes for students. Dee and Cohodes (2008), find that having a subject-certified teacher improves student achievement by 4-5 percent of a standard deviation, on average, with much greater benefits in math (12 percent of a standard deviation). Clotfelter, Ladd, and Vigdor (2010) also find that having a subject-certified teachers in math and English courses boosts student achievement by more than 10 percent of a standard deviation, though has no discernable impact on achievement in biology. For SPED students in Florida, Feng and Sass (2013) estimate that having certification in special education boosts student achievement by about 1.5 percent of standard deviation in math and roughly 2.5 percent of a standard deviation in reading. Understanding the impact of differential pay as a policy lever for hard-to-staff teacher shortage is crucial to solving this education crisis.

To combat subject-specific teacher shortages, several non-salary incentives have been employed, including scholarship programs for prospective teachers, housing subsidies, tuition subsidies for existing teachers changing fields and student loan forgiveness (Martin, 2007). Prior research on subject-based incentive schemes for teachers is quite limited.[4] Only two previous

[4] There is also some existing research on incentives to teach in high need schools and flexible pay. Steel, Murnane and Willett (2009) study a California program that offered a $20,000 bonus to a select group of new teachers that agreed to teach in high-need schools. Glazerman, et al. (2013) conduct an experimental analysis of the "Teacher Transfer Initiative," a federally funded initiative to that offered $20,000 in incentives for high-quality teachers to teach in low-achieving schools for two years. Falch (2010, 2011) studies a decade-long bonus program for Norwegian teachers. The program paid wage premiums to teachers in schools with chronic staffing shortages. Biasi (2021) studies how the introduction of flexible pay for teachers in Wisconsin raised teacher quality and attracted and retained high-value-added teachers to flexible pay districts versus traditional seniority and educational-attainment-based salary. Evans and Acosta (2023) survey 15 studies on the effectiveness of multiple types of government education policies and incentives across low- and middle-income countries for hard-to-staff schools.

studies analyze statewide subject-based bonus pay programs for teachers. Clotfelter, Glennie, Ladd, and Vigdor (2008) examine the impacts of a statewide bonus scheme that existed in North Carolina from 2001/02 to 2003/04. To qualify for the program teachers had to be certified as a secondary teacher in math, science, or special education and be working in a high-poverty or low-performing public school. Using triple difference estimator, they find the bonus program lowered turnover rates for the targeted teachers by 17 percent. Second, Feng and Sass (2017) study Florida's Critical Teacher Shortage Program, which was in effect from 1986/87 through 2009/10. The program provided loan forgiveness for teachers who were certified and taught in "high-need" subjects and (for a single year) retention bonuses. Employing a triple-difference estimator, they find the retention bonuses reduced the likelihood of teacher exit by as much as 32 percent.

This research makes multiple contributions. Our paper is the first (to our knowledge) to evaluate a multi-year statewide subject-specific pay differential system in which the bonus is not limited to teachers in high-poverty schools. This is important as school districts across the income distribution are looking to recruit and retain hard-to-staff teachers. We use detailed longitudinal teacher data in partnerships with state agencies to arrive at causal estimates of the impact of differential pay policy on teacher labor market decisions. This paper is also among the first to study the impact of state-wide bonus pay on attracting new teachers to the profession. Lastly, unlike related literature, we find that bonus pay alone without intentional and aligned incentives does not lead to desire outcome of increase of supply of new teachers nor more retention of existing teachers. These findings are informative to districts and policy makers that policy design and implementation is crucial to have a positive impact on teacher recruitment and retention.

The next section provides information on the context and design of Georgia's differential pay system and section 3 discusses the data we employ. Empirical methods and results are described in sections 4 and 5, respectively. The last section summarizes our findings and their implications for policy.

II. Background

Driven by concerns over shortages of qualified math and science teachers and a lack of new teachers entering those fields, the 2009 Georgia legislature passed House Bill 280 (HB 280), which produced a de facto differential pay scale for early-career middle and high school math and science teachers.[5] The legislation increased the pay of new math and science teachers to make it equal to that of a teacher with six years of experience:

> "(1) On and after July 1, 2010, and until such date as may be determined by the State Board of Education that mathematics, science, or both are no longer areas in which there an insufficient supply of teachers, a secondary school teacher in a local school system who is or becomes certified in mathematics or science by the Professional Standards Commission shall be moved to the salary step on the state salary schedule that is applicable to six years of creditable service, unless he or she is already on or above such salary step. From such salary step, the teacher shall be attributed one additional year of creditable service on the salary schedule each year for five years.
>
> (2) After five years, such teacher may continue to be attributed one additional year of creditable service on the salary schedule each year if he or she meets or exceeds student achievement criteria established by the Office of Student Achievement[6].
>
> (3) Upon expiration of five years, or any year thereafter that the teacher does not meet or exceed student achievement criteria as required by paragraph (2) of this subsection, such teacher shall be

[5]When signing the legislation into law, Governor Sonny Perdue noted that "Last year, Georgia produced only one physics teacher. This legislation will help us address the shortage of math and science teachers in the state." (Badertscher, 2011).

[6] Although part of the legislation, this performance criterion was never implemented.

> moved to the salary step applicable to the actual number of years of creditable service which the teacher has accumulated."
>
> (4) This subsection shall be subject to appropriations of the General Assembly.

The legislation also provided an annual stipend of $1,000 for kindergarten and elementary school teachers who possess an endorsement in mathematics or science. The K-5 incentive is not conditional on experience. Like the salary step increase for secondary math and science teachers, after five years, receipt of the K-5 stipend is conditional on student achievement criteria to be established by the Governor's Office of Student Achievement.

The condition that the bonuses were "subject to appropriations of the General Assembly" led the program to be implemented in such a way that the 6-12 salary-step increases became an experience-based bonus scheme that is not conditional on future employment. Eligibility for the program is determined by certification status and subject areas taught in October of each year. To be eligible for the grades 6-12 salary incentive, teachers must be (1) certified in math or science, (2) teach math or science in grades 6-12, and (3) have between 0-5 years of experience. A teacher does not qualify for the salary incentives if he or she is teaching math or science under a temporary ("non-renewable") certificate.[7]

A list of eligible teachers is compiled by the end of the calendar year and forwarded to the legislature for funding. Funds are appropriated by the legislature during their regular legislative session in spring of the calendar year following the October employment report. Funds are typically received by the Georgia Department of Education (GaDOE) in July and then dispersed to individual school districts. Teachers receive bonus checks in late August or early September,

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[7] Eligibility details are specified in Georgia Department of Education (2011) and Georgia Department of Education (2015a).

almost a year after their bonus eligibility is determined. If an individual is no longer teaching in Georgia public schools, they still receive the stipend.

Given the way in which the program was implemented and funded, the connection between teacher employment decisions and financial rewards is tenuous. Teachers typically make contractual decisions for the following year in April or May, though the teacher certification agency in Georgia, the Professional Standards Commission (GaPSC), allows teachers to resign until June 15 without consequence.[8] For a teacher who must make employment decisions for the following school year, their expected bonus would equal the product of three factors: the designated bonus amount for their level of experience, the probability that the legislature would continue funding the program, and the likelihood they know that the program exists.

The amount of the stipend is determined by the difference between the step on the state salary schedule based on a teacher's actual experience and the salary step for a teacher with six years of service. Even though some districts pay teachers more than what is stipulated in the state salary schedule, the amount of the bonus is determined by the applicable salary differences on the state salary schedule, not a teacher's actual salary. An example of the bonuses a new secondary math or science teacher with a bachelor's degree would receive is provided in Table 1. The bonuses total slightly more than $21,000 over six years.

Funds have never been allocated to implement the provision of the statute which extends salary incentives beyond five years of experience. Therefore, the bonus ends when a teacher has reached six years of experience. Since the current implementation of HB 280 does not extend

[8] The Georgia Professional Standards Commission's "Guidelines for Breach of Contract" states that "Administrators who are offering contracts to educators after June 15 who are currently under contract with another district may have their license sanctioned if the educator does not have a letter of release."

bonuses beyond five years, the provisions that make future bonuses contingent on performance have never been implemented.

The probability of continued program funding would depend on anticipated legislative budget decisions, which presumably would be a function of the health of the state economy and associated tax revenues. Griffin and McGuire (2015) say that one-third of local school districts they interviewed did not use the grades 6-12 bonus program as a recruiting tool due to concerns over the uncertainty of future state funding. Despite this perception, the Georgia legislature has continued to fund the bonuses for math and science teachers each year. In their study of bonuses in North Carolina, Clotfelter, et. al. (2008) notes that, "Principals also expressed concern that the program was likely to be impermanent, these concerns turned out to be justified as the state legislature canceled the program after its third year." However, despite this, the program was effective at reducing turnover, suggesting that funding uncertainty alone is unlikely to eliminate the efficacy of a bonus program.

The bonus program was not well publicized in the early years of implementation. Griffin and McGuire (2015) report that of the four associate deans from large university teacher preparation programs (representing one-third of all teacher preparation graduates) they interviewed, two were unaware of the bonus program and the other two did not know that the program had been funded. All four respondents indicated they had not received any communication from the Georgia Department of Education (GaDOE) or GaPSC regarding the grades 6-12 salary incentive.

The total number of teachers who received the bonuses, broken down by year and type of supplement, is presented in Table 2A. The number of first-time recipients, also broken down by year and supplement type, is presented in Table 2B. Due to the greater number of middle and high school math and science teachers (relative to elementary school teachers with a math or science endorsement) and the more generous supplement to middle and high school math and science teachers, the size of the grades 6-12 program is much larger. After the initial year, about 1,100 to 1,200 middle and high school teachers receive the salary supplement for the first time each year. In contrast, the first-time K-5 supplement recipients have ranged from 85 to just over 200 teachers each year. We therefore focus our analysis on the salary supplements for middle and high school math and science teachers.

III. Data

To estimate the effects of HB 280 on the supply of math and science teachers, we employ data from Georgia's statewide longitudinal database, Georgia's Academic and Workforce Analysis and Research Data System (GA•AWARDS). GA•AWARDS combines data from all educational agencies in Georgia as well as unemployment insurance (UI) records from the Georgia Department of Labor. Thus, individual students can be tracked from pre-K through post-secondary institutions and into the labor force. The database includes data from the 2006/07 school year forward and we have received data through the 2018/19 school year (the last full pre-pandemic year). Given that retention is determined by an individual's employment status in the following year, our analysis sample is limited to school years 2006/07 through 2017/18. Teachers can be linked to their college records and to the students they teach, though teacher-student linkages are only available for Race-to-the-Top participating districts in 2013/14 and 2014/15[9]. Although student-teacher linkages are limited, we can link students and teachers to schools for all years. We therefore use school-level

[9] Since teacher-student linkage is not available throughout all the years we can not estimate teacher's value-added scores nor evaluate the composition of the teacher's workforce (e.g. Biasi (2021))

averages of student characteristics to control for working conditions that may influence teacher labor market decisions.

The GA•AWARDS data include information on employee job codes, teacher certification and years of experience, which can be used to determine whether a teacher meets the requirements to qualify for a salary supplement. In addition, we received data from the GaDOE that indicates which teachers were designated to receive the supplement each year. The list of teachers who qualify (based on job, certification and experience information) does not always correspond to the list of recipients, however.[10] We therefore rely on the list of actual recipients to identify "treated" teachers.

IV. Econometric Methods

Below we describe our empirical strategy for estimating the effects of Georgia's differential pay system (HB 280) on the retention of existing teachers and the supply of new teachers.

A. Retention of Existing Teachers

To estimate the effect of differentiated pay on teacher retention we exploit the fact that teachers had to be both eligible for the differential pay program and the program had to be in place to receive payment. The program had three eligibility criteria: an individual had to be teaching secondary math or science, they had to be certified in the subject they were teaching, and they had

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[10] There are a number of interesting anomalies in the program's implementation. Teacher experience is based on Certified/Classified Personnel Information (CPI) data from the GaDOE. The CPI data track "credible" years of service, not actual years of service. For example, a teacher may not have received a step increase because of poor performance or insufficient funding and thus have fewer reported years of service than their actual years of classroom experience. There is also evidence that some districts may have miscoded science teachers as teaching social science. See Griffin and McGuire (2015) and Georgia Department of Education (2015b).

to have less than six years of credible service. We initially estimate a simple difference-in-difference model of the duration of teaching in Georgia public schools. Specifically, we estimate a Cox proportional hazard model of the form:

$$logit[\lambda(t_i)] = \beta_0 + \beta_1 E_i^{MS} + \beta_2 Z_t + \beta_3 (E_i^{MS} \times Z_t) + \beta_4 X_{it} \tag{1}$$

where $\lambda(t_i)$ is the probability that a teaching spell ends at the close of period t for teacher i, conditional on that spell lasting through period t.[11] E_i^{MS} is an indicator for teachers who ever meet the HB 280 eligibility criteria of being certified and teaching in either secondary math or science and having less than six years of experience. Z_t is an indicator that signifies the salary differential program was in place in year t. X_{it} is a vector of teacher and school characteristics that typically impact teacher attrition decisions (e.g. demographic characteristics of students at the school, teacher race and gender, etc.). The set of coefficients β_1 represent the difference in the hazard rates between ever-eligible teachers (those with less than six years of experience who are certified and teaching secondary math or science) and never-eligible teachers. β_2 represents the impact of being in the period in the differential pay program was in place (school years 2010/11 and later). The coefficient of interest is β_3, which represents the effect of being eligible for the differential pay program and being in a year in which the program was in effect.[12] β_3 therefore provides the simple difference-in-difference estimate of the impact of the differential-pay program on the exit hazard.

We can also break down the eligibility criteria into its separate components: certified and teaching middle/high school math or science and less than six years of experience. This allows us to estimate a "triple difference" model of teacher attrition:

[11] We determine the end of a spell based on whether a teacher is teaching in a Georgia public school in period t+1.
[12] Note, as described above, we use an indicator for actual recipients in place of the interaction term.

$$logit[\lambda(t_i)] = \beta_0 + \beta_1 C_i^{MS} + \beta_2 Y_{it}^{lt6} + \beta_3 Z_t + \beta_4\left(C_i^{MS} \times Y_{it}^{lt6}\right) + \beta_5\left(C_i^{MS} \times Z_t\right) + \beta_6\left(Y_{it}^{lt6} \times Z_t\right) + \beta_7\left(C_i^{MS} \times Y_{it}^{lt6} \times Z_t\right) + \beta_8(X_{it}) \quad (5)$$

where C_{it}^{MS} indicates teachers who were certified and teaching in math or certified and teaching in science, Y_{it}^{lt6} indicates teachers who have not reached their sixth year of service and Z_t indicates the years the program was in effect. The three two-way interaction terms in equation (5) represent: (i) the differential impact of being certified and teaching secondary math and science and having five or fewer years of service ($C_i^{MS} \times Y_{it}^{lt6}$), (ii) the impact of being certified and teaching secondary math or science in a year when the differential pay program was in effect $\left(C_i^{MS} \times Z_t\right)$, and (iii) the impact of being a teacher with less than six years of experience in the period the differential pay program existed $\left(Y_{it}^{lt6} \times Z_t\right)$. Lastly, the three-way interaction term, $\left(C_i^{MS} \times Y_{it}^{lt6} \times Z_t\right)$, represents the differential hazard rate of teachers who were certified and teaching secondary math or certified and teaching secondary science and possessed less than six years of experience during years in which the differential pay program existed. The coefficient β_7 is thus the difference-in-difference-in-difference estimate of the differential pay program's impact on the exit hazard.

B. The Supply of New Secondary Math and Science Teachers

There are two ways to become a public-school teacher in Georgia. The most common method is for potential teachers to complete a state-approved certification program, meet content assessment requirements, and then obtain a renewable professional teaching certificate. Alternatively, candidates with a bachelor's degree in any field can obtain a three-year non-renewable teaching certificate and begin teaching[13]. To transition to a renewable teaching certificate, individuals must either complete a traditional university-based preparation program or an alternate state approved educator preparation program.

As illustrated in Table 3, a bit more than one-third of middle and high school math and science teachers in Georgia earned their first baccalaureate degree in a field other than education, while just under two-thirds (59 percent) were education majors. While most new public-school teachers in Georgia obtained baccalaureate degrees in education, not all education majors end up as public-school teachers. Indeed, about one-third of education majors in Georgia do not become public-school teachers within a year of graduation. Thus, one way that pay differentials could impact the supply of new math and science teachers is to boost the likelihood that individuals with bachelor's degrees in education become public-school teachers.

The likelihood of becoming a public-school teacher will depend on both supply and demand factors for recent college graduates. As a proxy for general labor market conditions, we control for the unemployment rate. Higher unemployment rates indicate a depressed demand for workers generally and should be negatively correlated with employment probabilities of new graduates. As a crude measure of worker quality, we include the college GPA of education majors as an additional control.

To assess the effect of HB 280 on the supply of new teachers we estimate the following probit "difference-in-differences" model on the sample of all baccalaureate degree recipients with a major in education:

[13] Between SY 2015/2016 and SY 2016/2017 the certification categories changed in the data where observations in the "Clear Renewable" certification category were re-classified as "Standard Professional".

$$Prob\left[T_i^{Any} = 1\right] = \Phi\left[\gamma_0 + \gamma_1 D_i^j + \gamma_2 Z_t + \gamma_3 (D_i^j \times Z_t) + \gamma_4 U_t + \gamma_5 G_i\right] \quad (6)$$

where $Prob\left[T_i^{Any}\right]$ is the probability that individual i becomes a public-school teacher in any subject area within one year of receiving a bachelor's degree in education. D_i^j is an indicator for an education major in subject(s) j, where j represents the set of majors that are most common for secondary math and science teachers (see Table 3 above) and thus most likely to be able to take advantage of the HB 280 program. Z_t is an indicator that signifies the salary differential program was in place in year t. U_t is the unemployment rate in year t and G_i is the college grade point average of individual i. The coefficient γ_1 represents the increase in probability of becoming a public-school teacher if an individual majors in education subject(s) j, rather than in some other sub-discipline of education. The second difference is between the pre- and post-HB 280 periods (i.e. before and after 2010), γ_2. The coefficient of interest is γ_3, which represents the effect of graduating with an education major in subject(s) j in a year in which the differential pay program was in effect. The coefficient γ_3 provides the simple difference-in-difference estimate of the impact of the differential-pay program on the likelihood of becoming a teacher, i.e. the difference between graduates with majors(s) j and other education majors in the probability change from the pre-program program period to the program period.

We also conduct a similar analysis, focusing on becoming a secondary math or science teacher within one year of graduation, $Prob\left[T_i^{MS}\right]$:

$$Prob\left[T_i^{MS} = 1\right] = \Phi\left[\gamma_0 + \gamma_1 D_i^j + \gamma_2 Z_t + \gamma_3 (D_i^j \times Z_t) + \gamma_4 U_t + \gamma_5 G_i\right] \quad (7)$$

While (6) directly estimates the event of interest, becoming a secondary math or science teacher, it does not account for teachers who may not teach a middle or high school math or science course in their first year, but teach those courses later. Thus, we view estimates of the parameters in (6) and (7) as complementary. Equation (6) captures graduates who become teachers, some of which may never teach middle or high school math and science while equation (7) focuses on teachers who immediately teach middle and high school math and science courses but omits teachers who may teach in those subject areas in their second or later years of teaching.

In addition to altering the job choice of recent graduates with education degrees, the enhanced pay for early-career math and science teachers engendered by HB 280 could influence college major choice as well. While it is doubtful that the targeted pay increase would cause students interested in significantly different careers to switch to education, those already interested in teaching might be induced to change their specific major within education to be able to qualify for jobs that would be eligible for supplemental pay under HB 280. To estimate this potential longer-run supply effect, we estimate the following model:

$$Prob\left[D_i^j = 1\right] = \Phi[\delta_0 + \delta_1 FZ_i + \delta_2 FD_t^{Ed} + \gamma_3 U_t + \gamma_4 G_i] \tag{8}$$

where $Prob\left[D_i^j = 1\right]$ is the probability that individual I earns a degree in education field(s) j (conditional on having declared an education major by their sophomore year and earning a degree in education), FZ_i is our measure of exposure to treatment; it is the fraction of time between a student's sophomore year and the year they graduate that the HB 280 program was in place. FD_t^{Ed} is the number of BA/BS degrees awarded in the student's graduation year as a fraction of all BA.BS degrees awarded in that year; it is intended to capture the prevailing popularity of education majors in general. As in prior equations, demand is captured by the unemployment rate in year t, and the college grade point average of individual i, G_i.

V. Empirical Results

A. *Descriptive Analyses*

In Figure 1 we provide a graphical comparison between attrition of early-career teachers in general and early-career secondary math and science teachers. Annual attrition rates for both groups fall in the 10-13 percent range. Consistent with higher opportunity costs, in most years (8 out of 11) attrition rates are higher for secondary math and science teachers.

Figure 2 provides a comparison of attrition between middle and high school math and science teachers who received salary supplements as a result of HB 280 and those which never received a supplement, using a survival analysis framework. Teachers could be in the latter group for four reasons. First, some of these teachers entered teaching and left the Georgia public schools prior to the implementation of HB 280 in 2010/11 and thus never received a bonus. Second, some may have begun their careers as secondary math and science teachers but switched to other grades or subjects before the implementation of HB 280. Third, some math and science teachers may never have obtained non-temporary certification during the period of analysis. Fourth, there are some teachers who met the criteria for eligibility, but due to implementation issues, may have been left off the list of teachers who were to receive a bonus. To compare time until departure from Georgia public schools, only teachers observed during their first year of teaching are included in the sample.

The survival plots indicate that bonus recipients tended to have lower attrition than teachers who did not receive bonuses, particularly in the early years of their career, when supplements were the greatest. After five years of experience (when teachers could no longer receive the supplements) the two groups exhibit similar survival patterns. One potential problem with comparing ever and never-recipients, however, is that non-receipt is partly a function of when a teacher entering the Georgia public school system. Given the sample starts in 2006/07 and program implementation began in 2010/11, teaching spells greater than five years are only observed for teachers who had prior experience when the program began. To disentangle these cohort effects, we also present survival estimates for the subset of teachers who began teaching in 2010/11 or later. The results, provided in Figure 3, are similar to those for the full sample.

To quantify the change in teachers' exit rates across years and eligibility status we perform an event study. In Figure 4, prior to the policy change, exit rates are higher for those never eligible for the bonus but follow a similar pattern to those ever eligible for the bonus. After the introduction of subject-based bonus pay in 2010, the exit rate tends to increase for those ever-eligible teachers, relative to the non-eligible teachers.

B. *Quantitative Analyses – Teacher Retention*

As noted above, the data available to us begins in 2006/07, just four years prior to the start of the HB 280 program. Thus, we do not observe the first year of teaching for many teachers, but we do know how many years they had taught prior to the start of our analysis period and can conduct a survival analysis over the years they are observed. Put differently, the teaching history of some of the teachers in our sample are "left censored." As shown in Table 4, nearly 60 percent of teachers who taught middle/high school math or science during the sample period fall into this left-censored category. Descriptive statistics for both the full sample of middle and high school math and science teachers as well as the subsample of teachers observed for their entire career are presented in Table 4. In Georgia as in many states, teachers are predominately female and white.

For the subsample of 16,967teachers observed in their first year of teaching, roughly half, 8,367, ever received a salary supplement as a result of HB 280.[14]

Estimates from the difference-in-difference hazard models of exit from Georgia public schools are reported in Table 5. For the full sample that includes all teachers, the hazard ratio on the indicator for receipt of a supplement is 1.005, indicating that receiving differential pay increased the probability of exit by 0.5 percent. The estimate is not significantly different from zero, and thus we cannot refute the null that the program had no effect on the likelihood of teacher exit. Limiting the sample to teachers who ever taught math or science within the analysis period of 2006/07-2015/16, the point estimate is 0.94, indicating a reduction in the exit probability of six percent. This estimate is not statistically significant, however. If we further limit the sample to ever-math-or-science teachers who are observed from their first year forward, the estimated effect of the supplemental pay program on the probability of exit is large and positive indicating that exit rates are increased by 12 percent.

Estimates from the triple-difference model are presented in Table 6. The estimated impacts of the HB 280 differential pay program on the likelihood of exit are even stronger in this specification. For the full sample and the sample limited to teachers who ever taught math or science within the analysis period we find that receipt increases probability of exit by 68 to 73 percent. Unlike the previous two samples, when we limit the sample to ever-math-or-science teachers who are observed from their first year forward, the estimated effect of the supplemental pay program on the probability of exit is 0.68 indicating that exit rates are reduced by 32 percent.

[14] One potential source of misclassification among these teachers are anomalies in reported teacher experience. As a check, we also estimate models for the subsample of teachers who are observed as rookies and whose reported experience increases by one for every year they taught. Results are similar to those from the full sample.

One potential problem with the difference-in-difference and triple-difference estimators is potential violation of the “parallel trends” assumption. Under the difference-in-difference approach, the ever-treated and never-treated groups are allowed to have different exit rates prior to treatment, but it is assumed that the difference in the rates is constant over time. Thus, any change in the difference in the exit rates of the ever-treated and never-treated groups once treatment occurs is attributed to the treatment, yielding an estimate of the average treatment on the treated (ATT).[15]

A common approach to testing the parallel-trends assumption is to allow the “effect” of being in the treatment group to vary by year for both the pre- and post-treatment periods. In our context this is accomplished by including indicators for each year (except the base year) and then interacting each of the year indicators with either actual pay supplement receipt (in the post-treatment period) or meeting the requirements to qualify supplemental pay (in the pre-treatment period). If the parallel-trends assumption holds, the coefficients on the (qualified × year) interactions should be insignificant for the pre-treatment years. The (received bonus × year) interactions during the post-treatment period allow for the impact of the program to change over time (e.g. if there is initial uncertainty in likelihood of continuation, effects might be stronger in later years).

Table 7 provides estimates of the difference-in-difference and triple-difference models that allow for differential trends in both the pre- and post-treatment periods. The interaction between “qualified” and the two pre-treatment years (2009 and 2010) is not significant in the DD

[15] Recent advances to the difference-in-difference literature have been focused on critiques to estimating the ATT when there is staggered treatment (see Roth et al (2023) for a survey of the literature) unlike in this paper where there is a single treatment period.

specification (the 2008 base year interaction is omitted to avoid collinearity with the overall constant). Thus, we fail to reject the parallel-trends assumption for the DD model. However, this is not the case for the DDD specification. Each of the interaction terms has a positive and statistically significant interaction term, indicating that the parallel-trends assumption does not hold for the DDD specification. The actual-treatment/year interactions are somewhat variable, though there does appear to be a general upward trend over time. The apparent increasing impact of the pay supplement over time is consistent with the program becoming better known.[16]

C. *Quantitative Analyses – Teacher Supply*

In Table 8 we present estimates of the model that predicts the probability of becoming a public-school teacher, conditional on having earned a bachelor's degree in education. The first column focuses on the interaction between HB 280 and the most common major for middle and high school math and science teachers, Middle/Secondary Education. The second column presents estimates based on the three most common education majors of future middle and high school math and science teachers: Middle/Secondary Education, Special Education, and Math Education or Science Education (including specific science education disciplines). When the potentially impacted group is limited to middle/secondary education majors, having the HB 280 supplemental pay program in effect is found to boost the likelihood of becoming a public-school teacher by about 14 percent. When the list of potentially effected education majors is expanded to include Special Education and Math or Science Education, the availability of the HB 280 program is associated with an increase in the likelihood of becoming a public-school teacher by 13 percentage points. This effect seems to be mainly driven by the inclusion of special education majors and

[16] A potential countervailing factor is the average payout is changing over time as the experience distribution of qualifiers is changing.

thus must be interpreted with caution as the demand for special education teachers was increasing over the period in which HB 280 was instituted.

Table 9 presents estimates of equation (7), which also predicts the probability of becoming a public-school teacher, but a positive outcome is limited to middle and high school math and science teachers. In this case, we find no evidence that the HB 280 program increased the likelihood that graduates with an education degree would become secondary math or science teachers in public schools within one year of earning their college degree. When expanding the list of majors to include special education and math or science education, we estimates indicate a negative correlation between the existence of the HB 280 program and the probability of teacher middle or high-school math or science within one year of college graduation.

Finally, estimates of the impact of supplemental pay for math and science teachers on the choice of specific majors within education are presented in Table 10. Conditional on declaring an education major by their sophomore year, we cannot reject the null hypothesis that the supplemental pay program created by HB 280 had no impact of the specific major choice of eventual education baccalaureate degree recipients.

VI. Discussion

There is growing concern over shortages of teachers, though there is considerable variability in hiring and retaining teachers across disciplines. Finding and keeping teachers in secondary math and science is much more problematic than recruiting and retaining teachers in other subjects or grade levels. The cause of the shortages seems clear; the opportunity cost of teachers depends on the alternative wage they could earn in occupations outside of public-school teaching and thus the equilibrium wage varies across subject areas. Teachers with expertise in math and science are likely to garner relatively higher wages outside of teaching and thus economic theory implies a uniform pay scale is destined to produce shortages of teachers in those subject areas. One solution would be to raise the wages of math and science teachers relative to the wages of other teachers. Little is currently known, however, about the impact differential pay would have on the supply of new teachers and the attrition of existing teachers.

In this paper we analyze the impact of the only statewide differential pay program for general education teachers currently in existence[17] – Georgia's HB280 supplemental pay for math and science teachers – on both teacher retention and the supply of new teachers. Our findings indicate that Georgia's differential pay system has not had a significant impact on attrition rates for secondary math and science teachers. Similarly, we find no evidence the program increased the probability that education majors would immediately become secondary math or science teachers upon graduation. We also found no evidence of the differential pay program altering specific major choices within the education field.

The lack of any measurable impact on either the retention of existing teachers or the supply of new teachers does not mean that bonus systems are not a viable tool to reduce subject-specific teacher shortages. Indeed, prior studies in North Carolina and Florida (demonstrate that bonuses can substantially boost teacher retention Clotfelter, Glennie, Ladd, and Vigdor (2008) and Feng and Sass (2017)). Likewise, a district-run flexible pay scheme (more than just a bump in wages) that offers higher pay is an effective in attracting and retaining talented teachers (Biasi 2021) potentially due to the local flexibility and autonomy. Rather, our findings highlight the importance of carefully designing a compensation system and implementing it with fidelity. For

[17] The state of Hawaii, which is served by a single school district, recently adopted a policy that raised salaries of special education teachers by $10,000. See Theobald, et al. (2023).

example, the Georgia bonus system was implemented in a way that bonus receipt was not contingent on staying in the profession. We recommend a bonus receipt should be awarded earlier than a year after eligibility. It should be given before teachers make their next year labor market decisions in hopes to incentive them to stay in the profession. The policy we study was not well publicized and it was not set up to incentivize young professionals to attract and retain them in the field of education. In the future, design, promotion and communication of the bonus, incentive alignment and execution should be a priority to achieve the goals of a bonus program.

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VIII. Tables and Figures

Table 1. Salary Supplement for a 6-12 Math/Science Teacher in Georgia

Actual Years of Experience	Statewide Salary Schedule (Teacher with a Bachelor's Degree)		
	Salary Based on Actual Years of Experience	Salary Based on Six Years of Experience	Supplement
0	$33,424	$37,985	$4,561
1	$33,424	$37,985	$4,561
2	$33,424	$37,985	$4,561
3	$34,427	$37,985	$3,558
4	$35,460	$37,985	$2,525
5	$36,524	$37,985	$1,461
Total			$21,227

Table 2A. Number of Teachers Receiving Differential Pay by Year

Year	All Teachers				6-12 Math and Science Teachers		
	Did Not Receive	Received K-5 Bonus	Received 6-12 Bonus	Total	Did Not Receive	Received 6-12 Bonus	Total
2007/08	122,274	0	0	122,274	19,947	0	19,947
2008/09	122,475	0	0	122,475	20,572	0	20,572
2009/10	118,394	0	0	118,394	20,105	0	20,105
2010/11	109,786	0	3,765	113,551	22,891	3,765	26,656
2011/12	107,560	149	3,273	110,982	16,998	3,273	20,271
2012/13	105,121	208	3,105	108,434	16,896	3,103	19,999
2013/14	103,430	380	3,075	106,885	16,762	3,073	19,835
2014/15	103,487	529	3,186	107,202	16,583	3,185	19,768
2015/16	103,127	626	3,433	107,216	16,127	3,433	19,560
2016/17	103,295	868	3,456	107,619	16,668	3,456	20,124
2017/18	103,607	919	3,263	107,789	16,899	3,263	20,162

Note: The number of 6-12 math and science teachers is the number of teachers who met the subject area and certification requirements to be eligible for the grades 6-12 bonus. In the initial year of the program, SY 2010/11, there were two “consultative” job codes that were included in list of job codes that met the subject area requirement (one for regular ed. and the other for special ed.) but it was later determined that these codes were not aligned with the intent of the law and were subsequently dropped. There were 1,567 teachers who were designated as math and science teachers in SY 2010/11 because of these consultative codes. Of the 1,567, 305 received the 6-12 bonus.

Table 2B. Number of Teachers Receiving Differential Pay for the First Time by Year

Year	All Teachers				6-12 Math and Science Teachers		
	Did Not Receive	Received K-5 Bonus	Received 6-12 Bonus	Total	Did Not Receive	Received 6-12 Bonus	Total
2007/08	122,274	0	0	122,274	19,947	0	19,947
2008/09	122,475	0	0	122,475	20,572	0	20,572
2009/10	118,394	0	0	118,394	20,105	0	20,105
2010/11	109,786	0	3,765	113,551	22,891	3,765	26,656
2011/12	109,543	149	1,290	110,982	18,975	1,290	20,265
2012/13	107,207	85	1,142	108,434	18,849	1,140	19,989
2013/14	105,613	189	1,083	106,885	18,746	1,082	19,828
2014/15	105,832	203	1,167	107,202	18,589	1,166	19,755
2015/16	105,577	218	1,421	107,216	18,125	1,421	19,546
2016/17	106,212	346	1,061	107,619	19,037	1,061	20,098
1017/18	106,587	222	980	107,789	19,172	980	20,152

Note: The number of 6-12 math and science teachers is the number of teachers who met the subject area and certification requirements to be eligible for the grades 6-12 bonus. In the initial year of the program, SY 2010/11, there were two "consultative" job codes that were included in list of job codes that met the subject area requirement (one for regular ed. and the other for special ed.) but it was later determined that these codes were not aligned with the intent of the law and were subsequently dropped. There were 1,567 teachers who were designated as math and science teachers in SY 2010/11 because of these consultative codes. Of the 1,567, 305 received the 6-12 bonus.

Table 3. First BA/BS Degree of Teachers in Georgia who Ever Taught Middle/High Math and Science Courses during 2008-2019 and Earned a BA/BS Degree in Georgia in 2007-2018

First BA/BS Degree	Proportion of Math or Science Teachers with Known BA/BS Degree
Any Non-Education	0.409
Math/Statistics	0.083
Biology/Bio Med	0.089
Physical Sciences (incl. specific disciplines)	0.028
Engineering	0.009
Any Education Degree	0.591
Middle or Secondary Education	0.231
Special Education	0.131
Math Education or Science Education (incl. specific disciplines)	0.071
Early Childhood/Pre-K Education	0.071
Elementary Education	0.047
Observations	9,603

Table 4. Means of Characteristics of 6-12 Math and Science Teachers

	All 6-12 Math and Science Teachers			6-12 Math and Science Teachers Observed in their First Year of Teaching		
	All	Teachers Who Received Bonus	Teachers Who Did Not Receive Bonus	All	Teachers Who Received Bonus	Teachers Who Did Not Receive Bonus
	Mean	Mean	Mean	Mean	Mean	Mean
Female	0.7522	0.7150	0.7558	0.7196	0.7102	0.7288
Black	0.2473	0.2658	0.2455	0.3122	0.2555	0.3673
Hispanic	0.0090	0.0202	0.0080	0.0150	0.0151	0.0150
Asian/PI	0.0150	0.0255	0.0139	0.0213	0.0221	0.0205
Other Non-White	0.0061	0.0102	0.0057	0.0116	0.0127	0.0106
Renewable/Prof. Cert.	0.6621	0.7578	0.6529	0.4751	0.5963	0.3572
Ever Taught ELA	0.1529	0.0913	0.1588	0.1324	0.0834	0.1800
Ever Taught Math	0.4430	0.5411	0.4336	0.4591	0.5113	0.4083
Ever Taught Reading	0.0668	0.0227	0.0711	0.0637	0.0270	0.0994
Ever Taught Science K-5	0.0397	0.0251	0.0411	0.0516	0.0225	0.0799
Ever Taught Science 6-12	0.3002	0.3651	0.2940	0.2887	0.3550	0.2243
Ever Taught Social Studies	0.1168	0.0813	0.1202	0.1126	0.0764	0.1479
Ever Taught ESOL	0.0030	0.0031	0.0030	0.0018	0.0018	0.0017
Ever Taught Gifted	0.0032	0.0009	0.0034	0.0004	0.0005	0.0002
Observations	36,788	3,221	33,567	16,967	8,367	8,600

Table 5. Hazard Ratios for Difference-in-Differences (DD) Teacher Duration Models

	DD - Full Sample	DD - Math/Sci. Only	DD - Math/Sci. Only - Exclude Left Censored
Received Supplement in Current Year	1.005 (0.032)	0.937 (0.033)	1.118** (0.046)
Ever Qualified	0.820*** (0.015)	0.842*** (0.019)	0.639*** (0.020)
Program in Effect	0.963* (0.017)	1.289*** (0.047)	1.078 (0.074)
Female Teacher	1.011 (0.010)	0.937*** (0.016)	0.901*** (0.026)
Black Teacher	0.878*** (0.009)	0.912*** (0.019)	0.856*** (0.030)
Hispanic Teacher	0.990 (0.029)	0.976 (0.071)	1.057 (0.104)
Asian/PI Teacher	1.083* (0.043)	1.163* (0.070)	1.299** (0.105)
Other Non-White Teacher	1.085* (0.038)	1.054 (0.069)	1.040 (0.112)
School-Level Student Demographic Controls	✓	✓	✓
Year Controls	✓	✓	✓
Observations	870,210	248,749	78,272
Log likelihood	-689,157	-158,112	-54,366

School-level student demographics include Percent Black, Percent Hispanic, Percent Limited English Proficiency, Percent Foreign Born, Percent Primary Language Non-English, Percent Free/Reduced-Price Lunch, Percent Immigrant, Percent Homeless, Percent Retained in Grade, Average Age Within Grade, Percent Gifted and Percent with Disabilities. Reported estimates are exponentiated coefficients; Standard errors in parentheses.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6. Hazard Ratios for Triple-Difference (DDD) Teacher Duration Models

	DDD - Full Sample	DDD - Math/Sci. Only	DDD - Math/Sci. Only - Exclude Left Censored
Received Supplement in Current Year	1.679*** (0.080)	1.725*** (0.090)	0.676*** (0.100)
Ever Certified and Teaching Math or Science	0.684*** (0.018)	0.797*** (0.034)	0.639*** (0.068)
<6 Years of Experience	1.661*** (0.046)	2.418*** (0.149)	1.389 (0.249)
Program in Effect	0.953* (0.018)	1.194*** (0.060)	0.578** (0.111)
Certified and Teaching Math or Science × <6 Years of Experience	0.505*** (0.020)	0.377*** (0.019)	0.370*** (0.028)
Certified and Teaching Math or Science × Program in Effect	1.350*** (0.038)	1.100* (0.050)	1.398*** (0.134)
<6 Years of Exp. × Program in Effect	0.806*** (0.017)	0.731*** (0.037)	1.350 (0.249)
Female Teacher	1.011 (0.010)	0.937*** (0.016)	0.910** (0.026)
Black Teacher	0.878*** (0.009)	0.891*** (0.019)	0.827*** (0.029)
Hispanic Teacher	0.979 (0.029)	0.969 (0.070)	1.045 (0.103)
Asian/PI Teacher	1.107** (0.044)	1.178** (0.071)	1.300** (0.106)
Other Non-White Teacher	1.084* (0.038)	1.045 (0.068)	1.023 (0.110)
School-Level Student Demographic Controls	✓	✓	✓
Year Controls	✓	✓	✓
Observations	870,210	248,749	78,272
Log likelihood	-688,590	-157,698	-54,067

School-level student demographics include Percent Limited English Proficiency, Percent Foreign Born, Percent

Primary Language Non-English, Percent Free/Reduced-Price Lunch, Percent Immigrant, Percent Homeless, Percent Retained in Grade, Average Age Within Grade, Percent Gifted and Percent with Disabilities. Reported estimates are exponentiated coefficients; Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7: Hazard Ratios for Difference-in-Differences (DD) and Triple-Difference Models with Pre-/Post-Year Interactions

	DD - Full Sample	DDD - Full Sample
Received Supplement × Year 2011	0.950 (0.070)	1.994*** (0.168)
Received Supplement × Year 2012	0.904 (0.074)	2.056*** (0.193)
Received Supplement × Year 2013	1.000 (0.077)	2.286*** (0.205)
Received Supplement × Year 2014	1.006 (0.078)	2.335*** (0.211)
Received Supplement × Year 2015	1.190* (0.086)	2.778*** (0.239)
Qualified × Year 2009	0.874 (0.070)	2.280*** (0.216)
Qualified × Year 2010	0.944 (0.069)	2.461*** (0.220)
Ever Qualified	0.840*** (0.016)	
Ever Certified and Teaching Math or Science		0.679*** (0.019)
<6 Years of Experience		1.597*** (0.044)
Certified and Teaching Math or Science × <6 Years of Experience		0.374*** (0.019)
Certified and Teaching Math or Science × Program in Effect		1.350*** (0.040)
<6 Years of Experience × Program in Effect		0.840*** (0.019)
Female Teacher	1.011 (0.010)	1.011 (0.010)
Black Teacher	0.878*** (0.009)	0.878*** (0.009)

Hispanic Teacher	0.990 (0.029)	0.980 (0.029)
Asian/PI Teacher	1.083* (0.043)	1.107* (0.044)
Other Non-White Teacher	1.085* (0.038)	1.085* (0.038)
Year = 2009	0.917*** (0.016)	0.906*** (0.017)
Year = 2010	1.058*** (0.017)	1.054** (0.019)
Year = 2012	1.060*** (0.018)	1.060*** (0.018)
Year = 2013	1.140*** (0.019)	1.136*** (0.019)
Year = 2014	1.152*** (0.020)	1.151*** (0.020)
Year = 2015	1.133*** (0.020)	1.129*** (0.020)
School-Level Student Demographic Controls	✓	✓
Observations	870,210	870,210
Log likelihood	-689,160	-688,566

Exponentiated coefficients; Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 8. Probit Difference-in-Differences Estimates of the Probability of Becoming a Public School Teacher in any Subject Within One Year of Graduation, Conditional on Earning a Bachelor's Degree in Education

	Become a Public School Teacher Within One Year of Receiving Bachelor's Degree	
BA/BS in Middle School or Secondary Education × Program in Effect	0.144*** (0.049)	
BA/BS in Middle School, Secondary, Math, Science or Special Education × Program in Effect		0.126*** (0.037)
BA/BS in Middle School or Secondary Education	0.433*** (0.040)	
BA/BS in Middle School, Secondary, Math, Science or Special Education		0.415*** (0.030)
Program in Effect	-0.141*** (0.017)	-0.160*** (0.018)
College GPA	0.427*** (0.019)	0.396*** (0.019)
Unemployment Rate (in percent)	-0.114*** (0.004)	-0.111*** (0.004)
Constant	-0.597*** (0.069)	-0.559*** (0.069)
Observations	28,128	28,128

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9. Probit Difference-in-Differences Estimates of the Probability of Teaching Middle/High School Math or Science Within One Year of Graduation, Conditional on Earning a Bachelor's Degree in Education

	Teach Middle or High School Math or Science in a Public School Within One Year of Receiving Bachelor's Degree	
BA/BS in Middle School or Secondary Education × Program in Effect	-0.054 (0.054)	
BA/BS in Middle School, Secondary, Math, Science or Special Education × Program in Effect		-0.206^{***} (0.058)
BA/BS in Middle School or Secondary Education	1.316^{***} (0.043)	
BA/BS in Middle School, Secondary, Math, Science or Special Education		1.756^{***} (0.048)
Program in Effect	-0.002^{*} (0.029)	0.113^{**} (0.048)
College GPA	0.066^{**} (0.029)	-0.057^{*} (0.032)
Unemployment Rate (in percent)	-0.023^{***} (0.006)	-0.012^{*} (0.007)
Constant	-1.738^{***} (0.107)	-1.982^{***} (0.122)
Observations	28,128	28,128

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10. Probit Estimates of the Probability of Earning a BA/BS in Specified Education Majors, Conditional on Having Declared an Education Major by Sophomore Year and Earning a BA/BS Degree in any Education Major

	BA/BS in Middle School or Secondary School Education	BA/BS in Middle School, Secondary School, Math, Science or Special Education
Fraction of Time Between Sophomore Year and Graduation Year Program in Effect	-0.047 (0.069)	0.012 (0.058)
College GPA	-0.147^{***} (0.038)	0.176^{***} (0.032)
Unemployment Rate (in percent)	0.009 (0.013)	-0.030^{***} (0.011)
BA/BS Degrees in Education in Graduation Year as a Fraction of All BA/BS Degrees	-1.119 (0.782)	-0.867 (0.631)
Constant	0.154 (0.650)	-0.375 (0.529)
Observations	11,619	11,619

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure 1. Percentage of Teachers Leaving Georgia Public Schools by Year (Teachers with 5 or Less Years of Experience)

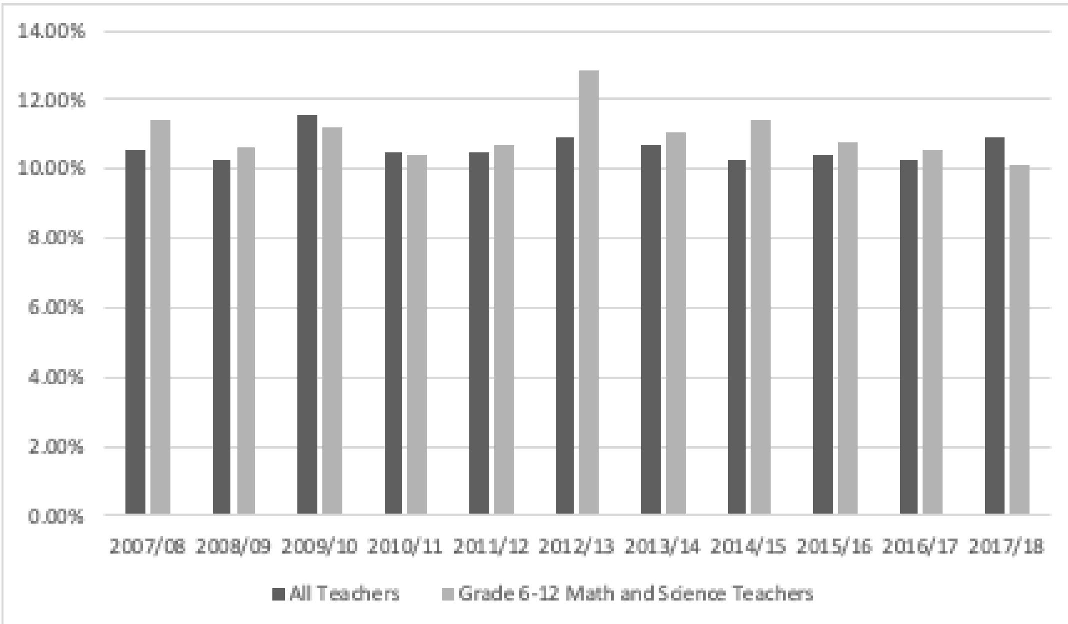

Figure 2. Kaplan-Meier Survival Estimates of Teaching in Georgia Public Schools (Math/Science Teachers Observed in Their First Year of Teaching, 2006/07-2017/18)

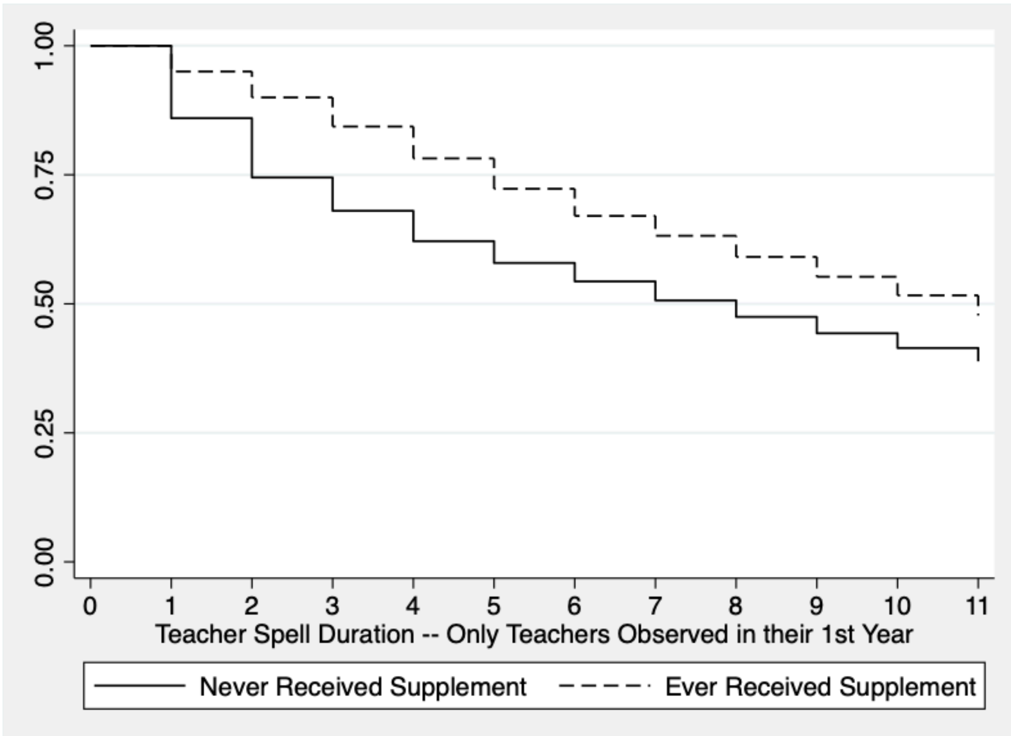

Figure 3. Kaplan-Meier Survival Estimates of Teaching in Georgia Public Schools (Math/Science Teachers Observed in Their First Year of Teaching, 2010/11-2017/18)

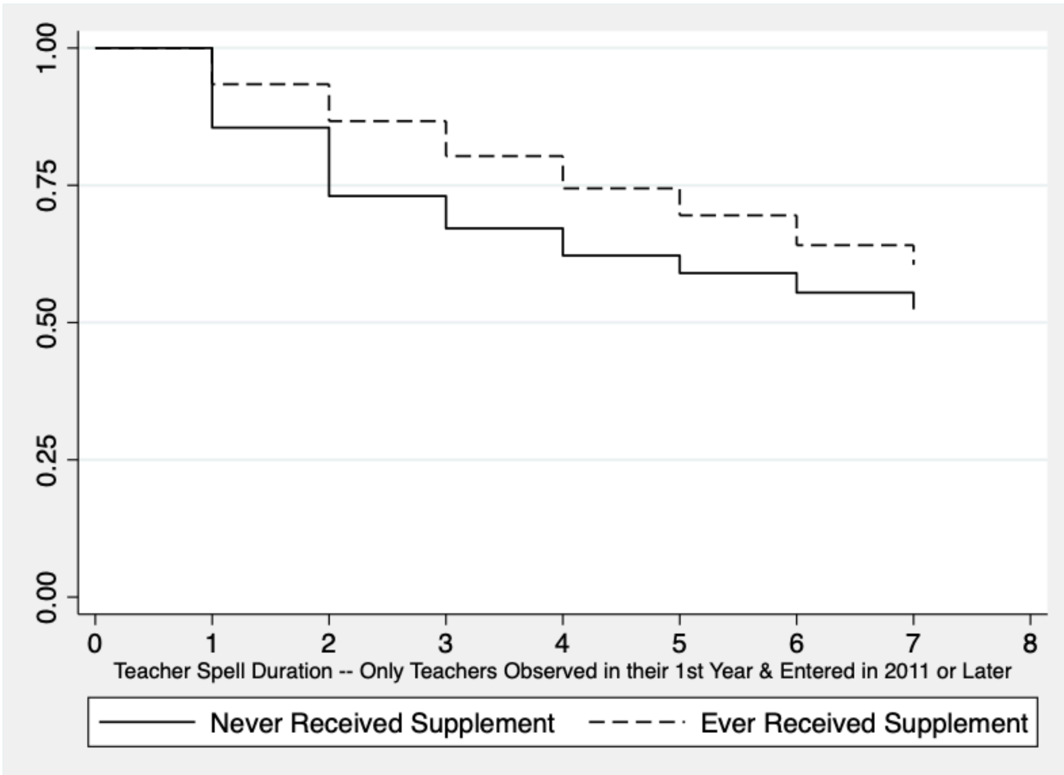

Figure 4: Teacher Exit Rates by Bonus Eligibility, 2007/08 – 2017/18