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Salary Incentives and Teacher Quality: The Effect of a District-Level Salary Increase on Teacher Retention

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In a political environment in which student achievement gains are increasingly demanded, policymakers focus more than ever on teacher turnover and its potential negative effects on student learning. Nationwide, approximately 17% of teachers leave their schools every year (Planty, 2008), and the attrition rate is even higher in urban districts and schools that serve large populations of low-performing, non-white, and low-income students (Boyd, Lankford, Loeb, & Wyckoff, 2002; Hanushek, Kain, & Rivkin, 2004; Ingersoll, 2001). School districts nationwide are beginning to experiment with policies that leverage teacher compensation in an effort to retain teachers. Such policies often include increasing teacher salaries and introducing targeted incentives to recruit and retain particular teachers. This strategy is growing in popularity across California and the nation (see, for example, Koppich & Rigby, 2009; Milanowski, 2002; Strunk, Zeehandelaar, & Weinstein, 2009).

Existing research suggests that teacher turnover may have disruptive effects in schools, regardless of the kinds of teachers who leave the profession (Guin, 2004; Ronfeldt, Lankford, Loeb, & Wyckoff, 2011). For this reason, may be important to reduce turnover of teachers across the profession. Furthermore, in light of evidence that highly-effective teachers have a strong and lasting effect on student outcomes (Chetty, et al., 2010; Rivkin, Hanushek, & Kain, 2005; Sanders & Rivers, 1996), it is also important to consider how retention efforts differentially influence the behavior of the most effective teachers.

While there is evidence to suggest that teacher retention in general is improved by increases in compensation (e.g., Murnane, Singer, & Willett, 1989; Reed, Rueben, & Barbour, 2006), there is not yet sufficient evidence on whether salary increases can improve retention in urban school districts and in schools serving high proportions of minority and low-income students. Moreover, there is inconclusive evidence on whether such salary incentives can be effective in retaining the most highly-effective teachers.

To address this gap, this study assesses the effect of a salary increase on teacher retention in the San Francisco Unified School District (SFUSD). Specifically, I examine the effect of the Quality Teacher and Education Act of 2008 (QTEA), which introduced an overall salary increase ($500-6,300, varying by placement on the salary schedule), a $2,000 bonus for teaching in a hard-to-staff (HTS) school, and retention bonuses ($2,500 after the 4th year and $3,000 after the 8th year). These aspects of QTEA were intended to improve teacher retention both district-wide and within particular schools that have historically had problems with teacher turnover.

QTEA implementation corresponded with a downturn in the economy that could impact teacher retention even in the absence of the policy. Thus, to estimate the causal effect of QTEA compensation elements on teacher retention, I compare teachers who are arguably similar in the way that they would be affected by the economy, but differently affected by QTEA. I use a difference-in-differences approach to study changes in teacher retention for these "targeted" teachers compared to those that were not targeted for salary increases by the policy. Employing a robust dataset combining nine years of administrative data linking teachers, students, and schools in SFUSD, I answer the following questions:

- To what extent did teacher retention improve for teachers targeted by QTEA's:
    - Overall salary increases?
    - Retention bonuses?
    - Hard-to-staff school bonuses?
- Did the retention of highly-effective teachers improve after QTEA?

In what follows, I review the literature forming the theoretical background for this work, provide an overview of QTEA and its compensation provisions, review the data sources used in this paper, provide the methods employed, and present the findings for each of the research questions. Finally, by way of conclusion, I use survey and case study research to shed light on the mechanisms that might explain results.

Literature review

Nationwide, approximately 17% of elementary and secondary teachers exit their school each year, with half of these exits (8%) due to transfers to a different school and the other half of these exits (9%) due to leaving teaching (Planty, 2008). High-poverty public schools have much higher rates of teacher turnover than low-poverty schools (21 vs. 14%).[1] This finding is well established in the literature on teacher retention; schools with high teacher turnover are more likely to serve large populations of low-performing, non-white, and low-income students (Boyd, Lankford, Loeb, & Wyckoff, 2003; Hanushek, Kain, et al., 2004; Ingersoll, 2001). Urban schools in particular have lower retention than their suburban counterparts (Boyd, et al., 2002; Ingersoll, 2001).

It is not immediately clear that teacher attrition has uniformly negative effects on students and schools. If highly-effective teachers are the ones that stay and the less effective teachers who leave are replaced by better teachers, then this compositional change can have positive effects. However, while some evidence indicates that more effective teachers are more likely to stay (Boyd, Lankford, Loeb, Ronfeldt, & Wyckoff, 2011; Goldhaber, Gross, & Player, 2007; Hanushek & Rivkin, 2010), the difference between those who stay and those who leave is often not large and there is evidence that schools with high levels of turnover experience organizational dysfunction (Guin, 2004) and lower student achievement, even after controlling for teacher quality (Ronfeldt, et al., 2011). The weight of the evidence suggests that reducing

[1] Analysis is based on retention in the 2003-04 school year. Schools were considered high-poverty if 75% or more of their students were considered eligible for free- or reduced-price lunch.

turnover, especially in schools with very high rates of attrition and especially with an eye towards retaining more effective teachers, can benefit schools and students.

Teachers leave their schools (and the profession) for many reasons, including retirement and family responsibilities (Beaudin, 1995; Ingersoll, 2003) as well as dissatisfaction with characteristics of the job (Boyd, Grossman, Lankford , Loeb, & Wyckoff, 2007; Ingersoll, 2001). A robust body of literature demonstrates that teaching conditions predict turnover, including teacher collaboration and support (Johnson, 2006; Weiss, 1999), school facilities (Buckley, Schneider, & Shang, 2004), geographic location of the school (Boyd, Lankford, Loeb, & Wyckoff, 2005), the effectiveness of the administrators (Boyd, et al., 2010), and student characteristics such as race and income (Loeb, Darling-Hammond, & Luczak, 2005; Scafidi, Sjoquist, & Stinebrickner, 2007).

The conclusion from this literature is that teacher dissatisfaction with the characteristics of their job prompts attrition. So to increase teacher retention, policymakers over the past decade have focused on improving teachers' job satisfaction. For example, some of these strategies address the nature of teachers' work, and invest in programs such as teacher induction and mentoring, additional time for staff collaboration and professional development, and teacher leadership (Mangin & Stoelinga, 2008; Smith & Ingersoll, 2004; Weiss, 1999).

In recent years, policy-makers are beginning to experiment with a more market-based approach, introducing monetary incentives for specific teachers or in targeted positions to improve recruitment and retention (see, for example, Koppich & Rigby, 2009; Milanowski, 2002; Strunk, et al., 2009). The theory behind the use of salary incentives to improve teacher retention is that teachers make career decisions based on their preferences for many things, including their satisfaction with working conditions and the salary that they receive; if their compensation is increased, they may accept less ideal working conditions in exchange for the higher pay. Such incentives provide a "compensating differential" for potentially unattractive job characteristics (Hanushek, 2007; Hanushek, Rivkin, Rothstein, & Podgursky, 2004).

Indeed, there is a substantial body of literature showing that higher salaries can improve teacher retention system wide. For example, Murnane, Singer and Willet (1989) have shown that elementary school teachers paid $2,000 per year less than average leave the classroom an average of one year earlier. In a more recent study, Reed, Rueben and Barbour (2006) show that an overall salary increase of $4,400 instituted in California in the 1990s reduced the probability that a new elementary school teacher would exit teaching by 17%. Along the same vein, Krieg (2006), estimated that an additional $1,000 of salary in the state of Washington diminishes female attrition by 0.17%.

However, there is less evidence on the effectiveness of policies designed to improve teacher retention in urban schools and schools serving high proportions of low-income and minority students. Recall that a goal of the QTEA salary incentives was to increase teacher retention both across a district that serves more low-income and minority students than other local districts (SFUSD), as well as within the hardest-to-staff schools. As such, the current study of the SFUSD salary changes provides an opportunity to contribute to several underdeveloped areas of the literature on salary incentives. Specifically, the project contributes to the small amount of work in the following three areas: (1) the effect of salary differentials in urban school districts, (2) incentives aimed at increasing teacher retention in hard-to-staff schools, and (3) evidence on how highly-effective teachers respond to these incentives.

(1) There are a few relevant studies of salary differentials, most of which employ state-wide datasets to investigate whether salary differences across districts affects teacher retention

for higher-paying districts, after controlling for student characteristics. The idea here is that most variation in salaries is between (rather than within) districts, and if teachers are sensitive to compensation, they should respond by demonstrating higher retention rates in higher paying districts.[2] Imazeki (2005) uses Wisconsin data to show that districts with higher salaries have lower transfer rates but that higher salaries have no impact on teachers leaving the profession. Also, the author finds that higher salaries in Milwaukee (which serves more low-income and high-poverty students by far than other "urban" districts in the state) do not have a substantial effect on improving teacher retention. Similarly, in another study looking at between-district salary variation in Texas, Hanushek, Kain, and Rivkin (1999) demonstrate that teacher attrition is lower when district salaries are higher relative to other local districts, but that this effect disappears when school and student characteristics are included. These studies provide some weak evidence that higher salaries can improve retention in urban school districts, but that even salaries much higher than other districts relatively may not be enough to increase retention in the most urban districts in a region.

Recent research on district-level salary interventions supports this idea. In an evaluation in Chicago of the Teacher Advancement Program (TAP), which provides performance incentives (along with reforms designed to improve teacher support and accountability), Glazerman and Seifullah (2012) found a small retention effect, but the impacts were not uniform across years, cohorts, or subgroups of teachers. Similarly, in a study in Denver of ProComp, which provided monetary incentives that are knowledge and skills-based, performance-based, and market-based, Fullbeck (2012) detected a weak effect on teacher retention, however found a greater impact on

[2] Lankford, Loeb, & Wyckoff (2002) show that after five years, 40% of new teachers stay in the same school; 18% transfer to a different school within the same district, 11% of teachers transfer to a school in another district, and 30% leave teaching altogether, and that teachers who transfer often move to higher paying school districts. Thus, it stands to reason that a higher salary within a school district could both retain teachers within the profession and also discourage transfer behavior.

retention rates for schools with high ProComp participation and for high-poverty schools. The study, however, does not control for secular changes during the time period, so it is difficult to establish causality for even this weak effect.

(2) The current project also contributes to the small amount of existing evidence on whether salary interventions can have an effect on retention specifically in targeted schools. Of the small number of studies investigating this question, most produce null results. For example, Steele, Murnane and Willett (2010) find that a California state incentive policy (which provided $5,000 per year for four years to academically talented new teachers teaching in the state's lowest performing schools) had no significant effect on the retention patterns of new teachers after four years. Similarly, there was no significant improvement in teacher retention as a result of the Massachusetts Signing Bonus Program, which offered a $20,000 bonus to alternate route new teachers as an incentive to teach in the state's highest need schools for four years (Fowler, 2003). A notable exception is an $1,800 retention bonus for math, science, and special education teachers in North Carolina's lowest-performing schools. Clotfelter, Glennie, Ladd and Vigdor (2008b) showed that a North Carolina policy that targeted hard-to-staff schools and subjects reduced turnover rates by an average of 17%. However, in other work studying the same intervention, the authors show that the policy had a weak or no effect on retention, and that teachers and principals are not aware of the policy (2008a).

(3) Finally, there is very little work investigating whether higher quality teachers respond differentially to salary and incentives, despite theory to suggest that highly-effective teachers may be more responsive to salary incentives. This idea comes from the literature on information and job search, which suggests that more productive workers are more aware of salary in general because of a desire to be compensated for their quality (McCall, 1970). In the context of

education, this could mean that teachers who are "highly-effective" (i.e., those who contribute more to their students' learning) may be more sensitive to increases in compensation, since they better estimate their own worth and want to be compensated accordingly. This could be particularly true in a teacher labor market, where teachers are (most often) not compensated for their productivity within a school district and the primary way for them to increase their compensation is to transfer to a school district with a higher salary.

While there is some evidence that teacher salary increases can improve teacher quality as measured by student outcomes (e.g., Loeb & Page, 2000), other studies show no effect (Hanushek, et al., 1999; Springer, et al., 2010). Besides being inconclusive, the existing research also does not separate the effect of teacher retention from other possible mechanisms of teacher quality such as teacher recruitment or motivation effects. In one of the only studies directly investigating the effect of differential salary increases on the retention of high-quality teachers, Clotfelter, Ladd, and Vigdor (2011) found that salary bonuses (ranging from $1500-5000) were actually *less* effective in retaining teachers with strong pre-service qualifications (i.e., average licensure test scores and competitiveness of undergraduate institution) than average teachers.

The conclusion from this literature is that teachers matter, and in general, they respond to higher levels of compensation with increased retention both in their schools and in the profession. However, there is very little research investigating whether a salary increase can be effective in retaining teachers in urban schools or districts, and even work studying whether such interventions can be successful in retaining highly-effective teachers. This is an important gap to fill, as such policies continue to proliferate. Building on the extant literature, in my three research questions, I use causal methods to isolate the effect of each of QTEA's salary incentives on teacher retention. Since QTEA's salary incentives should both increase the attractiveness of working in SFUSD and in high-poverty schools in the district, for each analysis I explore the extent to which QTEA altered retention patterns overall and within schools. Finally, because there is a system-wide goal of retaining high-quality teachers and theory to suggest that such teachers may differentially respond to salary incentives, I also investigate the extent to which retention patterns changed for highly-effective teachers.

Background: The Quality Teacher and Education Act in SFUSD

The San Francisco Unified School District (SFUSD) is a large urban school district and will serve as a good case study for investigating the effect of a district-level salary increase. SFUSD is the 60th largest school district in the country and the fifth largest school district in California.[3] San Francisco is in the sixth largest Combined Statistical Area (CSA) in the country (second in California after Los Angeles),[4] and SFUSD is the largest school district within this CSA. Like many large urban school districts, SFUSD sees itself in competition for teachers with local suburban districts, which may be perceived as "easier" places to work. Indeed, on measurable characteristics, SFUSD does seem to have more challenging working conditions than other local school districts. As shown in Table 1, of the 186 public school districts in the CSA of San Jose-San Francisco-Oakland, SFUSD is in the top quartile of the percent of students who are English Learners and who are eligible for Free or Reduced Price Lunch (76th and 83rd percentile, respectively). In addition, 39% of SFUSD's schools are in the bottom decile of achievement among other schools in California (which is in the 83rd percentile compared to other local districts); 44% percent of students lack proficiency in English Language Arts (which puts SFUSD in the 69th percentile); and 39% percent lack proficiency in math (which puts SFUSD in the 53rd percentile). These demographic and performance metrics seem to have an effect on

[3] http://nces.ed.gov/pubs2001/100_largest/table01.asp
[4] http://www.census.gov/popest/metro/tables/2009/CBSA-EST2009-02.xls

teacher quality in the district: 5% of SFUSD's teachers lack a full credential and 7% have two or fewer years of teaching experience. These metrics place SFUSD in 75th and 79th percentile amongst other local districts, meaning that SFUSD teachers have lower levels of experience and education than most other school districts in this CSA. This disparity between SFUSD and local districts in the qualifications of their teachers led many policy makers in SFUSD to make a change.

[Insert Table 1 here.]

The Quality Teacher and Education Act

The main impetus for the introduction of QTEA was a concern among education stakeholders in San Francisco that teacher salaries were too low, and that in order to increase teacher quality, teachers had to be paid more. Many in the district believed that in order to lure teachers to SFUSD, and retain them, the salary needed to be higher than in neighboring suburban districts. Mark Sanchez, who was Board of Education president when QTEA was passed, said, "Why would [a teacher] be teaching at a really difficult school and get paid really poorly and get treated by a system that didn't have structures in place to treat you well? … Why would you put up with that if you didn't need to? You could go somewhere else suburban to teach or go into another profession and do better … financially and probably emotionally" (Hough & Loeb, 2009, p. 6).

In June 2008, the voters of San Francisco approved QTEA, a parcel tax authorizing SFUSD to collect $198 per parcel of taxable property annually for 20 years.[5] These revenues add

[5] The only way for the district to significantly increase teacher salaries was for the money to come from a parcel tax. The lack of alternative options is a direct result of California's Proposition 13 in 1978, which set a 1% cap on property tax rates. As part of that legislation, the parcel tax emerged as one of few sources of discretionary tax revenue available to school districts; local governments are allowed to levy "special taxes" subject to the approval of two-thirds of the electorate. For more detail on the passage of QTEA, see Hough (2009) and Hough and Loeb (2009).

up to over $500 per student per year[6] and since March 2009 have been used to fund a general increase in teacher salaries, as well as a number of changes in teacher compensation and support for school improvement initiatives, such as technology and charter schools. The largest portion of QTEA's revenue goes toward teacher compensation increases. As a result of QTEA, teachers receive an across-the-board salary increase that varies by placement on the salary schedule. As shown in Table 2, for teachers with 3 and 10 years of prior experience, respectively, 2009-10 increases are $7,030 and $2,028 (compared to 2007-08). This represents an increase of 15% and 3%, respectively. These salary increases were much larger than surrounding districts during the same time period and made SFUSD salaries more competitive. Table 2 shows, for example, that while SFUSD salaries were more than $6,370 lower than San Jose Unified's for Step 3 teachers before QTEA, they were $660 higher after QTEA. In addition, as a result of QTEA, some teachers began receiving targeted bonuses. Teachers working in one of 25 schools designated hard-to-staff receive an additional $2,000, and teachers receive retention bonuses of $2,500 after four years of service in SFUSD and $3,000 after eight years.[7]

[Insert Table 2 here.]

QTEA implementation period. Assessing whether QTEA was able to improve teacher retention in SFUSD requires a careful definition of the QTEA implementation period. As shown in the timeline in Figure 1, QTEA was passed in June 2008, and the first salary payments were made to teachers in March 2009. In the 2008-09 school year, teachers received half of the overall QTEA salary increase that they received in 2009-10 (and every year thereafter). Teachers began

[6] Funding per student is an estimate based on parcel tax revenue projections ($28,529,226) and student enrollment at the time of passage (55,497).

[7] QTEA also introduced a $1,000 bonus for teaching in a hard-to-fill subject, but the effect of this bonus will not be explored here for several reasons. First, it is difficult to isolate the effect of the bonuses, as all teachers in those subjects received the bonuses, preventing the establishment of a control group. Second, the bonus was reduced to $500 in the 2010-11 school year, and the targeted subjects were reduced from math, science, bilingual education and Special Education to just Special Education.

receiving the retention bonus in September 2009 (for 4th and 8th year of service the prior year), and in January 2010 teachers in hard-to-staff schools began receiving the bonus for service in that school year (2009-10).

In thinking about retention effects, it is the salary in the following year that will encourage teachers to return; teacher return-rates between 2009-10 and 2010-11 would be a function of the salary that teachers would gain if they stayed for the 2010-11 school year. Thus, teacher retention in the 2007-08 school year or prior would not have been affected by QTEA, as teachers gained nothing from QTEA in this time period. Similarly, teacher retention in 2009-10 and after *would* be affected (as QTEA salary incentives were in full effect during this time). It is more difficult to ascertain whether the 2008-09 period should be included as a pre- or post-QTEA period. I argue that, since QTEA was passed in June 2008, by the time the policy was passed, teachers had already made their decisions for the following year, so 2008-09 should not be included in the QTEA implementation period.

[Insert Figure 1 here.]

There were some changes between the 2009-10 and 2010-11 school year to QTEA policy elements due to budgetary issues within the district. There was an economic downturn corresponding with QTEA implementation, and the district experienced severe budget cuts from the state of California (Buchanan, 2009). District leaders anticipated a shortfall in state funds of $113 million for the 2011-12 and 2012-13 school years. In dealing with this unanticipated reduction in the SFUSD budget, the district and union negotiated budget cuts and layoffs over much of the 2009-10 school year, and the use QTEA funds was included in this negotiation. As part of their agreement, in May 2010, the district Superintendent and UESF leadership announced that some QTEA funds would be reapportioned to save teacher jobs; while QTEA's overall salary increases and the hard-to-staff school bonus would remain intact, the retention bonus would be reduced for the 2010-11 and 2011-12 school years (to $1,250 and $1,500 for 4th and 8th year teachers, respectively).[8] The reduction in the size of the retention bonus was announced in May 2010, well after when teachers would have needed to make their arrangements for the following year. However, there was uncertainty about how QTEA funds would be used in 2010-11, which certainly could affect teacher response to the incentives. Because of these complications, I use the 2009-10 and 2010-11 school years as my primary definition of the implementation period, but I will test for varied retention effects by including 2008-09 in the implementation period and testing for varied effects in the 2009-10 and 2010-11 school years.

Defining "targeted" teachers. This paper explores the effects of three kinds of compensation increases: overall salary increases, retention bonuses, and bonuses for teachers in hard-to-staff schools. As discussed above, if QTEA has an effect on retention, we would expect to see increases in retention behavior for teachers who would be targeted by QTEA's various salary incentives in the year in question. Policy design and implementation determines which teachers are "targeted," and will be discussed below for each salary incentive.

Overall salary increase. In the time period before QTEA to after, teacher salary increases ranged from 0% to 13% for teachers depending on their placement on the salary schedule. In creating the new salary schedule, district officials frontloaded the salary increases, and then determined step and column increases conditional on availability of funds. This strategy resulted in an uneven distribution of teacher salary increases across teachers at different levels of

[8] Other policy elements were also reduced. For full information on this agreement, see http://www.uesf.org/prop_a/Prop.A-TA-10-12.pdf

experience and education. This variation presents a unique opportunity for studying the effect of the salary increases, since some teachers are targeted by large salary increases and others are not.

In SFUSD, as in most districts, teachers are placed on the salary schedule corresponding with their number of years of experience and their continuing education units. Teachers' salaries increase annually as they accumulate additional years of experience, and the schedule they are on depends on their level of education.[9] Figure 2 shows the distribution of the percentage increases across teachers with different levels of experience on the nine different SFUSD salary schedules (comparing 2009-10 salaries to 2008-09 salaries before QTEA). For teachers with just a bachelors degree (BA), salary increases as a result of QTEA never go above 6%; for teachers with a BA plus 30 units, salary increases hover around 10% for teachers with zero to five years of experience, and then drop quickly to under 6%; and teachers with a BA plus 60 units experience the highest salary increase, with the amount again decreasing sharply after five years of experience.

[Insert Figure 2 here.]

In the analyses that follow, teachers are considered "targeted" if they would have received a large salary increase (due to QTEA) compared to the pre-QTEA period if they returned in the following year. Figure 2 provides some visual evidence that a cutoff of 6% salary increase is reasonable for determining which teachers were targeted, but this will be further discussed below.

Retention bonus. The district paid retention bonuses to teachers when (if) they returned after their 4th or 8th year of service in SFUSD, so teachers were "targeted" for this bonus in their 5th or 9th year of service. (Teacher years of service in SFUSD in any position, not just teaching,

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[9] Note that in SFUSD, there are 9 schedules: three B schedules are for credentialed teachers, three C schedules are for uncredentialed teachers, and three S schedules are for department heads.

qualified them for this bonus.) The decision to provide bonuses in these particular years was based on a sense among district leaders that retention suffered in these years, although there is not necessarily data to support this idea. It is important to note that implementation of this bonus at the district-level was problematic. Due to inconsistent records for identifying teacher years of service in SFUSD, according to one source, approximately 200 teachers who should have received bonuses initially did not.[10] While these problems with payouts could certainly affect teacher response to the bonuses, it does not affect the definition of targeted teachers for the purposes of this study.

Hard-to-staff school bonus. The district paid hard-to-staff school bonuses to teachers annually if they taught in one of 25 schools designated hard-to-staff, so teachers were "targeted" for this bonus if they taught in a specified school. The implementation of this bonus changed between 2009-10 and 2010-11 and thus requires more elaboration. The schools were initially designated "hard-to-staff" in April 2009 (for the 2009-10 school year); the selection process included review of relevant data, but ultimately schools were selected at the discretion of district leaders. In September 2010, four of the hard-to-staff schools were redesignated and replaced with other schools (for the 2010-11 school year). Even though these changes could make it difficult for QTEA to have the effect in the medium- to long-term, I argue that short-term analysis of effects is possible because of the timing of the announcements of the changes; modifications to the hard-to-staff school list were announced in September 2010, which is after the 2010-11 school year has already started. Thus, teachers in hard-to-staff schools in 2009-10 would have every reason to expect that they would receive the bonus in 2010-11. Similarly, teachers' behavior in the newly-designated schools could not have been affected because they did not know about the bonuses in time to respond accordingly. For this reason, I define teachers

[10] For more detail on policy implementation, see Hough, Loeb, and Plank (2010).

as “targeted” for the hard-to-staff school bonus if they teach in a school initially designated hard-to-staff.

Information dissemination. In order for teachers to respond to the incentives, they needed to know about them. Teachers received information about the salary and bonus changes from both the teachers’ union (United Educators of San Francisco, or UESF) and the SFUSD central office. From UESF, teachers could access information on the website, and received notifications via emails sent to the entire membership. Teachers could also access information from the SFUSD website. In addition, SFUSD sent notices to teachers receiving bonuses at the start of the 2009-10 school year (co-signed by UESF leadership), included notices in weekly newsletters posted at the schools, and sent notifications over district email. These efforts by the district and the union likely increased teachers’ knowledge of the reform. However, some potential barriers to information receipt remained. Most importantly, SFUSD teachers are not well connected through district e-mail, so email dissemination may not have been effective.

Another way teachers learned about salary and bonuses was by actually receiving the payments. The across-the-board salary increase is built into the salary schedule and pay-out to teachers is distributed across paychecks with specific line item indicators. The district pays the targeted incentives as lump sums: the retention bonus comes in the fall of the year following the 4^{th} or 8^{th} year of service and the hard-to-staff school bonuses come one semester after service. Both bonuses appear on paychecks as a specific line item.

Data

The analyses presented in this paper take advantage of a unique and robust database that includes nine years of administrative data and original surveys of teachers in one of these years (2009-10). In what follows here, I detail each data source.

Administrative data

Through combining a diverse array of data sources, including SFUSD administrative data and publicly available data, I constructed a longitudinal database which links all teachers, students, and schools in the district from 2002-03 through 2010-11. These data allow me to examine teacher attrition both in the district overall and within schools during the observation period. At the teacher level, this database includes teacher demographics, teaching experience within SFUSD and prior, teacher placement on the salary schedule, and receipt of QTEA salary and bonuses. At the school level, the database contains measures of school attributes retrieved from the California Department of Education including school level, student enrollment, average class size, the percentage of teachers with a credential, the percentage of students who qualify for free or reduced priced lunch, the percentage of minority students, the percentage of students who are designated as English Learners, the percentage of students who are proficient in state math and English Language Arts tests, and statewide measures of school achievement by the California Department of Education. At the student level, this dataset contains detailed data on student demographics and achievement.

The analyses that follow require tracking teacher retention behavior over the time period in question. In order to do so, I restrict the database to employees who were ever teachers (as defined by SFUSD salary schedules) in the time period 2002-03 through 2010-11. In each year, I can identify whether these individuals stayed in their current position, transferred within SFUSD, or left the district.[11] In this way, I track individuals both who remain in teaching positions and who transfer into non-classroom positions (such as at the district office or working at multiple school sites). This full dataset includes 32,926 teacher-year observations.

[11] Note that retention behavior is calculated separately for each year. Thus, if a teacher took a leave of absence in one year, he/she is counted as leaving in that year, and then if they return the following year and stay, that is counted as a separate observation.

After constructing the retention variables in this way, I restrict the database to teachers *in each year* (as specified by the salary schedule) who work in only one school site. In this way, I am able to observe retention behavior in each year for school-site teachers, which is the population of most interest. Over the nine year time-frame, 6,024 unique individuals served as teachers in SFUSD, with a total of 25,291 teacher-year observations. Table 3 displays the total number of observations in each year, with the retention behavior observed in the following year.[12] Overall, 82% of teachers return to their schools the next year, 12% leave the district, and 6% transfer to other positions within SFUSD.

[Insert Table 3 here.]

Identifying "targeted" teachers. Above I detailed which teachers are targeted by QTEA's salary increases. In analyses that follow, I compare changes in retention comparing the "targeted" teachers to the non-targeted teachers. Here I detail how I identified targeted teachers in the data.

Overall salary increase. It is the anticipated salary in the following year that determines whether a teacher would be targeted by QTEA's salary increases. Thus, to identify the salary increase teachers would receive as a result of QTEA, I estimated the increase that a teacher would gain as a result of QTEA in the next year by adding an additional year of experience and assuming teachers would have the same number of continuing education units (and thus be on the same salary schedule) in the following year if they returned.[13] As shown in Figure 3, the distribution of salary increases as a result of QTEA approximates a bimodal distribution, with a

[12] Recall that 2010-11 is not included; due to availability of data, I am not able to observe teacher retention patterns in the following year (2011-12). Teacher return rates for 2010-11 are captured in the row for 2009-10.

[13] The teacher salary variables seem to work properly (most importantly, they are linear within teacher across time, indicating that as teachers number of years in the district increases, their years of experience increase at the same rate on the salary schedule). Thus, adding an additional year of experience to estimate the salary in the next year seems like an acceptable approach.

cutoff around 6%. Thus, I consider teachers to be "targeted" by QTEA overall salary increases if their salary in the following year would be 6% or more higher as a result of QTEA than it would have been before. Using this cutoff to determine which teachers are targeted, 26% of teachers are in the "targeted" group across all years. The average percentage increase in salaries as a result of QTEA is 10% for those in the targeted group, and 3% for those in the non-targeted group.

[Insert Figure 3 here.]

Retention bonus. A teacher's number of years of service within the district determines whether he or she is "targeted" for the retention bonus; teachers in their 4th and 8th year teaching would expect to receive a bonus in the following year if they returned.[14] Unfortunately, unlike the experience variables associated with salaries, the variables within the administrative data indicating years of service within SFUSD are problematic. For example, the data on years of experience within the district do not increase linearly within teachers across time; in fact, a subsequent year may have a lower magnitude than its prior year. After manual cleaning of this variable, I am able to construct an indicator of years of service within SFUSD that is linear within each teacher and appears to approximate teachers' actual years of service within the district. In the full sample, I identify 6% of teachers as in their 4th year and 5% as in their 8th year over the entire time period.

To test the accuracy of this constructed variable, I compare my identification of years of service with teachers' actual receipt of retention bonuses in 2009-10 and 2010-11 (the first years this bonus was awarded). As shown below in Table 4, 66% of the teachers that I identified as being in their 5th year in SFUSD actually received the bonus (after their 4th year of service) in 2009-10, and 67% in 2010-11. For teachers I identified as being in their 9th year of service (targeted for the bonus after their 8th year), 45% of them actually received the bonus in 2009-10,

[14] Note that the retention bonus is awarded after 4 or 8 years of service in SFUSD in any role, not just teaching.

and 69% in 2010-11.[15] While the accuracy of the identification improved in 2010-11, the match between teachers identified as being in their 9th year of service and those receiving the bonus is still relatively low.

[Insert Table 4 here.]

My inability to perfectly predict retention bonus receipt may be due in part to the district's similar difficulty in identifying teachers for bonuses. District staff reported that approximately 200 teachers who should have gotten the bonus did not initially, of 250 that were ultimately awarded (Hough, et al., 2010). The difficulty in awarding these bonuses was due to faulty data systems which could not accurately identify teachers' years of service. It seems possible that my variable is actually quite close to the actual variables used to award the retention bonuses. Of the teachers who received the retention bonus that was intended for service after their 4th year, 81% of them were in the group of teachers that I identified as having five years of experience in 2009-10 and 75% of them were in this group in 2010-11. For teachers receiving the bonus after their 8th year, 60% of them were identified as being in their 9th year in 2009-10 and 79% of them were in this group in 2010-11. It is possible that the fact that only 66% of the teachers I identified as 5th year teachers received the bonus (as shown in Table 4) is not an artifact of my identification of years of service, but rather a reflection of how the bonuses were actually allocated, meaning that a substantial teachers who should have received the bonuses may not have.

In any case, only 45% of the teachers I identified as in their 9th year of service actually received the bonus in 2010, and this is too low of an identification to be used reliably in analysis. Thus, in the analyses that follow, I will primarily study the effect of the retention bonus for those

[15] Note that the denominator here is the full dataset of employees who were ever teachers (N=32,926); since the retention bonus is awarded to employees for years of service (rather than years of teaching), this is the appropriate denominator for this description.

in their 5th year of service. (However, I will also include a specification where I include test for an effect for 9th year teachers.) Even though it would be preferable to have a 100% identification rate of the teachers who are targeted for the retention bonus, 64% is a strong number and likely reflects the true distribution of the bonus. In addition, even if I have over-identified teachers as 5th year teachers, this would give a downward bias to my analysis of retention effects, rather than overestimating possible effects.

Hard-to-staff school bonus. SFUSD initially developed a list of hard-to-staff schools in April 2009, and in September 2010, they redesignated four of these schools and replaced them with four other schools. As discussed above, the timing of the announcements of the changes does not complicate a short-term analysis of effects, as the changes to the hard-to-staff school list were announced in September 2010 - too late for them to have affected teacher retention in that year. Thus, I define hard-to-staff schools as those that were initially designated for the 2009-10 school year. Across all years, these 25 schools employed approximately 26% of the teachers in the sample.

Identifying effective teachers. A goal in this paper is to develop a measure of teacher quality to employ in studying whether teacher retention improved particularly for highly-effective teachers as a result of QTEA. While some researchers use teacher characteristics such as years of experience, education, or certification as a proxy for teacher quality (Goe, 2007), these measures explain little of the total variation in teacher quality as measured by gains in student test scores (Goldhaber, 2008). For this reason, I have chosen to identify highly-effective teachers using teacher "value-added" scores. The benefit of using such scores is that they provide a direct measure of teachers' contributions to student achievement. However, such measures also have their drawbacks; research has shown that value-added measures can be instable for individual teachers from year-to-year (Atteberry, 2011; 2007; McCaffrey, Sass, Lockwood, & Mihaly, 2009), and such scores can only be estimated for teachers in grades and courses that are tested annually, often making them available for only a small subset of teachers. Nonetheless, these scores have been used in a growing body of research that shows they are related to other measures of teaching quality (Grossman, et al., 2010; Hough, et al., Forthcoming; Tyler, Taylor, Kane, & Wooten, 2010), and that the students of teachers with high value-added scores succeed in other ways later in life (Chetty, et al., 2010).

In this paper, I use a standard teacher-by-year fixed effects model that includes lagged student test scores (in both subjects) from the prior year, a set of time-invariant student demographic characteristics, and grade and teacher-by-year fixed effects (see, for example, McCaffrey, Koretz, Lockwood, & Hamilton, 2003; McCaffrey, Lockwood, Koretz, Louis, & Hamilton, 2004). This model is formalized for math outcomes below:

$$(1) \qquad MathAch_{igjst} = \alpha MathAch_{igjst-1} + \gamma ElaAch_{igjst-1} + X_{igjst}\beta + W_s\varphi + \theta_g + \delta_{jt} + e_{igjst}$$

Student i, in grade g, in teacher j's classroom in school s in year t, has a math achievement score ($MathAch_{igjst}$, standardized within grade, subject, and year) which is a linear function of prior achievement in both subjects the previous year; a vector of student demographic characteristics (X_{igjst}) including race, gender, English language status, parental education status, special education status, enrollment in the Gifted and Talented Program, eligibility for free/reduced price lunch program (which serves as a proxy for socioeconomic status); a vector of time-invariant school-level means of the student-level covariates (W_s); the grade level (θ_g); and the teacher to which the student is exposed in the given year (δ_{jt}). The key parameter of interest is δ_{jt}, which captures the average achievement of teacher j's students in year t, conditional on prior skill and student characteristics, relative to the average teacher in the same subject and grade. The student-level covariates are intended to capture the background factors of students that account for variability in student test scores. In essence, each student's test score is adjusted for the fact that, on average, students of certain prior achievement, race/ethnicities, genders, language status, etc., perform, on average, at different levels. The goal in employing student level covariates is to eliminate the bias due to non-random sorting of students into teachers' classrooms.[16]

The scores were generated from a database that follows students longitudinally as they encounter teachers from kindergarten through graduation (or their entry/exit to the SFUSD district).[17] The sample is restricted to teachers who taught math or English language arts (ELA) in grades three through eight since 2000-01 – when California began to administer the current statewide standardized test, called the California Standards Test (CST). High school teachers are excluded from the study because it is more difficult to clearly attribute test scores to the correct teacher when students have the opportunity to take multiple math or ELA courses each year. In addition, math course-taking can vary dramatically from year to year in high school (e.g.,

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[16] There are many alternative specifications I could have used here. The first is a teacher fixed-effect model, rather than a teacher-by-year fixed-effect model. Such a model can seem attractive in that it aims to capture a "true" (and unchanging) level of ability. However, such a model is not employed here, as I want to allow for variations in effectiveness within teacher (e.g., due to growth or decline in teaching ability) to observe whether teaching effectiveness by year is related to teacher retention behavior. Another possible approach is the use of a student fixed effect in analysis, as such an approach compares only teachers who have taught the same students across years, thus controlling for all observed and unobserved, time-invariant student factors, perhaps strengthening protections against bias. Student fixed effects are not employed here, however, since recent research has shown that student fixed effects estimates are more biased than similar models using student covariates (Kane & Staiger, 2008). Another approach that could be used here is a model with school-level fixed effects to control for time-invariant school-level factors that might influence the outcome of interest. However, the inclusion of school fixed effects fundamentally changes the meaning of δ_{jt}, which then becomes a comparison of adjusted student outcomes among teachers in the same school. As a result, valid comparisons can only be made within the same school, while nothing can be learned about the relative performance of teachers in two different schools. However, in this analysis, I am interested in understanding the retention behavior of teachers district-wide and how it relates to overall effectiveness. Thus, in lieu of school fixed effects, a vector of school-level characteristics (W_s) is included, to compare student outcomes in schools that are similar on these dimensions. Finally, classroom covariates are not included in the model, since year-specific classroom variables are completely collinear with a teacher-by-year fixed effect (McCaffrey, et al., 2003).

[17] The value-added scores for this study were created as part of a larger project studying teacher quality in SFUSD; for further detail on construction and validity of the scores, see Atteberry (2011).

geometry, algebra, statistics, calculus, etc.), and it becomes difficult to meaningfully interpret differences in year-specific standardized test scores from one year to the next.[18] Finally, the dataset is restricted to teacher-years in which the teacher is linked to students with complete covariate information, including current-year test score, prior-year test scores, race, gender, English language status, and free-reduced price lunch program eligibility.

Table 5 provides the total number of teachers in each year and the percentage in each year with teacher-by-year value added scores. Note that I have dropped scores where the number of students used to estimate the value-added score is fewer than 10, since there is a dramatic increase in the estimated standard errors for classes that have fewer than ten students.[19] Over the entire time period, 19% of teachers have an ELA score, 19% have a Math score, and 24% have a value-added score in either ELA or Math.

[Insert Table 5 here.]

Surveys

As part of this study, I surveyed all teachers in the district in the spring of the 2009-10 school year.[20] These surveys included questions about QTEA implementation and teachers' awareness of QTEA's compensation elements. All surveys were web based[21] and were administered to participants using multiple email addresses on file with SFUSD. I sampled 3,116 classroom teachers 53% responded.[22]

[18] For instance, if a student has a lower-than-expected test score in ninth grade and then a higher-than-expected test score in the following year, this could be due to the fact that she experienced a particularly effective tenth grade teacher. But it could also simply be due to the fact that the student is better at geometry than she is at Algebra II.

[19] McCaffrey et al. (2009) and Goldhaber and Hansen (2008) implement ten and fifteen-student minimums, respectively, after conducting similar analyses.

[20] Teachers who responded to the survey were entered into a lottery to win one of 50 $150 gift cards.

[21] The actual survey instrument can be found online at http://suse.qualtrics.com/SE/?SID=SV_3KjOwbfuWNudn6c&Preview=Survey&BrandID=suse

[22] For more detail on the survey administration, see Hough, et al. (2010)

Method

Measuring retention effects

The fundamental goal in this study is to investigate whether average school-level and/or district level retention improved in SFUSD after QTEA. However, I cannot simply compare retention rates before and after implementation of the policy because of the economic downturn that occurred simultaneously. When QTEA was passed, unemployment in the San Francisco Bay Area was 5.6%, but was 9.6% by the following year and continued to climb.[23] This downturn in the economy has serious implications for studying QTEA. The scarcity of alternative jobs, either in teaching or in other occupations, could have led to an increase in teacher retention (both in schools and district-wide) even in the absence of QTEA. Control for secular trends is often warranted, but it is particularly important in this time frame. Thus, in my investigations, I employ methods to isolate the causal effect.

A first look into the effect of QTEA on teacher retention in SFUSD would be simply to observe return rates for teachers before and after implementation of the policy. Such an approach is not causal but tells us generally if retention changed in the period after QTEA implementation. Looking at the basic percentages (as presented in Table 6), we see that before QTEA, 80% of teachers stayed in their school, 13% left the district, and 6% transferred to other positions within SFUSD. After QTEA, 85% of teachers stayed in their school, 9% left the district, and 6% transferred to other positions within SFUSD. This data pattern shows that retention within schools increased by nearly five percentage points overall after QTEA. Table 6 also shows that rates of in-school retention are lower in hard-to-staff schools both before and after QTEA (72% and 80%, respectively), compared to non-hard-to-staff schools (83% and 87%, respectively).

[Insert Table 6 here.]

[23] http://www.bls.gov/lau/#tables

Formalizing this descriptive analysis, in my first investigation, I look at the retention behavior of teachers before and after QTEA in the context of a multinomial logit model. I am interested here in understanding changes in the proportions of teachers who stayed in their school, transferred to another school in SFUSD, or left the district before and after QTEA. Because this outcome is categorical, a multinomial logit model is appropriate; in such a model, the probability of each occurrence is estimated relative to a base outcome (Long, 1997). In this case, I am interested in whether more teachers both stayed in their schools and stayed in the district after QTEA compared to leaving. This method allows me to investigate simultaneously whether more teachers stayed in their schools and the district relative to leaving after QTEA:

$$(2) \qquad P_{ij+1}^{h} = \frac{\exp(\beta_0^h + \beta_1^h QTEA_{j+1} + \beta_2^h SIG_{j+1})}{\sum_{g=1}^{G} \exp(\beta_0^g + \beta_1^g QTEA_{j+1} + \beta_2^g SIG_{j+1})}$$

In this model, the probabilities of leaving the district in the next year (h=1), returning to the same school the next year (h=2), or remaining in the district and transferring to another SFUSD school the next year (h=3) are a function of whether the year in question is in the QTEA implementation period. The additional variable *SIG* indicates whether the school received a School Improvement Grant in the 2009-10 school year. In the 2009-10 school year, 10 schools in SFUSD received a School Improvement Grant[24] from the federal government; as a result of this program, some of these schools replaced 50 percent of their staff for the 2010-11 school year (Tucker, 2010). For this reason, I include a variable that identifies these SIG schools in 2009-10, to control for any changes in retention in the 2010-11 school year that occurred as a result of this program.[25]

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[24] http://www2.ed.gov/programs/sif/index.html
[25] Note, this variable only identifies the 10 SIG schools *in the year* we would expect retention to be affected by the program (i.e., when year j+1 = 2010-11). Of the 10 SIG schools, 7 were also designated hard-to-staff.

This approach might suggest a QTEA effect, but it is not causal. To estimate the causal effect of each compensation element, I use a similar model, but I create a sample of teachers who are arguably similar in the way they were affected by the economy, but different in the way they were affected by QTEA. I then isolate the "QTEA effect" on teacher retention using a difference-in-differences approach comparing the change in retention behavior of teachers who were "targeted" for salary increases to those who were not targeted.

Figure 4 graphically presents a simplified version of this approach, looking only at within-school retention rates. In this depiction of a hypothesized effect, those teachers that would have been targeted for QTEA before the policy have lower retention rates (which seems possible since these teachers may have been targeted for a reason). After the implementation of QTEA, the average retention rate increases both for the "targeted" teachers and the "non-targeted" teachers, perhaps as a result of the economic downturn discussed above. However, if the retention rate increases more for teachers in the targeted group, the "QTEA effect" is the difference between retention rates pre-and post-QTEA for the targeted teachers and pre-and post-QTEA for the non-targeted teachers.

[Insert Figure 4 here.]

For each analysis, I use this difference-in-differences approach within a multinomial logit model that examines the effect of QTEA on annual teacher return behavior. The specific model is as follows:

(3)

$$P_{ij+1}^{h} = \frac{\exp(\beta_0^h + \beta_1^h TARGETED_{ij+1} + \beta_2^h QTEA_{j+1} + \beta_3^h TARGETED_{ij+1} * QTEA_{j+1} + \beta_4^h SIG_{j+1})}{\sum_{g=1}^{G} \exp(\beta_0^g + \beta_1^g TARGETED_{ij+1} + \beta_2^g QTEA_{j+1} + \beta_3^g TARGETED_{ij+1} * QTEA_{j+1} + \beta_4^g SIG_{j+1})}$$

The probabilities of leaving the district in the next year (h=1), returning to the same school the next year (h=2), or remaining in the district and transferring to another SFUSD school the next year (h=3) are a function of whether the teacher would have been targeted for the various salary increases in the next year (*TARGETED*), whether the year in question is in the QTEA implementation period (*QTEA*), and the interaction of whether the teacher was targeted for salary increases in the time period after QTEA (*TARGETED*QTEA*). (Again, *SIG* identifies the 10 schools in 2009-10 that received a School Improvement Grant.) This approach adjusts for secular trends in the teacher labor market during this time that affected all teachers; observing the effect of QTEA for those who were targeted compared to non-targeted and looking at this difference before-to-after allows me to isolate the effect of QTEA on those teachers that were most affected by the policy.

Recall, multinomial logit models analyze categorical data by estimating the probability of each occurrence relative to a base outcome (Long, 1997). In the case of the overall salary increase and the retention bonus, I am interested both in whether more teachers stayed in their schools and in the district (transferring schools) after QTEA compared to leaving; thus I use "leaving the district" (h=1) as the base scenario in these models. Thus, a QTEA effect would be indicated by increases in both the rates of staying in schools and transferring relative to leaving the district. Note that the hard-to-staff school bonus only incentivizes staying in that school, thus both transfers out of the school and leaving the district would indicate that the policy did not work. For this reason, when studying the effect of the hard-to-staff school bonus, I use "returning to the same school" (h=2) as the base scenario; a QTEA effect would be indicated by a decrease in the rates of both leaving and transferring for targeted teachers.

Because I employ a multinomial logit model, in every specification, further analysis is required to understand the difference-in-differences estimator (Buis, 2010). In the model presented above in Equation 3, the interaction *(TARGETED*QTEA)* tells us how the QTEA effect differs between targeted and non-targeted teachers, but it does so in multiplicative terms. To answer the research questions presented above, I need to compare the marginal effect, specifically to test whether there is a difference in retention rates before and after QTEA between targeted and non-targeted teachers. Equation 4 details this approach:

(4) *[Return rate(Targeted, Post-QTEA) – Return rate(Targeted, Pre-QTEA)]*
– [Return rate(Non-targeted, Post-QTEA) – Return rate(Non-targeted, Pre-QTEA)]

In order to accurately estimate the difference-in-differences within the context of the multinomial logit model, I compute this marginal difference for every specification. The result provides an estimate for the amount that retention increased for the targeted teachers before and after QTEA, differencing out the post-pre differences for the non-targeted teachers. Thus, this estimate represents the difference-in-differences estimator and is the statistic of interest in all analyses. Using this approach, I study three of QTEA's compensation elements in different models to isolate the "QTEA effect." Each case requires a different analytic sample to isolate the effect and ensure that I am comparing teachers who are similarly affected by the economy, but differently affected by QTEA.

Overall salary increase. Because the salary increase introduced as a result of QTEA varies across teachers at different placements on the salary schedule, QTEA's overall salary increase can be thought of as a natural experiment. In other words, if we can assume that the variation in salary increases does not affect changes in retention behavior by any route other than through the salary increase itself, any changes we see in retention for targeted teachers can be attributed to QTEA's salary increases.

However, QTEA's salary increases are a function of teaching experience, which is also related to how teachers would be affected by the economy. Specifically, less experienced teachers are most affected by QTEA, but they also may be most affected by changes in the economy. Teaching is a seniority-driven profession, and teachers with 1-2 years of experience are most often those targeted by layoffs. Thus, to isolate the QTEA effect, and ensure that I am comparing teachers who would be similarly affected by the economy, I exclude first and second year teachers (in year j) and teachers with fewer than three years of service within SFUSD who are more likely to receive layoff notices or to be non-reelected. I also exclude teachers with more than 16 years of teaching experience, whose retirement decisions may be affected by the economy. As shown above in Figure 2, teachers with 3-16 years of experience are differently affected by QTEA's overall salary increases, however, they should be similarly affected by the economy.[26] Restricting the population in this way brings the analytic sample to 14,277 teacher-year observations (from 25,291 observations in the general dataset).

As discussed above, teachers are considered targeted for the overall salary increase if they would have gained 6% or more as a result of QTEA. (In this analytic sample, 30% of teachers are "targeted.") If the increases are effective, we would see an increase in retention in year j+1 if teachers were targeted for the overall salary increase in that year.

In this model, I test several additional specifications. First, because of the complications in QTEA implementation (discussed above), I will test a specification in which I include 2008-09 in the implementation period and test for varied effects using 2009-10 and 2010-11 as separate variables. (Equation is presented in Appendix A.) Second, I investigate whether there is a varied effect when I limit the sample to hard-to-staff schools.[27] We might expect to see a larger

[26] Note that teachers identified as having three years of experience are in their third year of teaching in year j.
[27] For consistency across the paper, I use the 25 schools initially designated hard-to-staff.

effect in such schools, both because they may be more difficult places to work and because they have lower retention rates both before and after QTEA and thus have more room for improvement. (See Table 6 for evidence to this effect.) Finally, I include a specification in which I restrict the sample even further by years of experience, including only teachers with 4-11 years of experience in year j; the idea here is that that these teachers are arguably more similar than teachers with 3-16 years of experience, but still very differently affected by QTEA's overall salary increases.

Retention bonus. Teachers are considered targeted for the retention bonus if they were in their 4th or 8th year of teaching in year j. If the bonuses are effective, we would see an increase in retention in the year that targeted teachers receive the additional compensation (year j+1). Because of the data complications discussed above, I focus on the effect of the bonus on the retention of 5th year teachers. To isolate the effect of QTEA on the teachers targeted for the retention bonus, I limit the sample to teachers with three to five years of service within SFUSD (in year j), as those with four years of service are targeted for the bonus, and individuals with three or five years of service within SFUSD should not be differently affected by the economy. I also limit the sample to teachers with 3-16 years of total teaching experience (in year j), to exclude first and second year teachers and very experienced teachers whose retention behavior may be affected by changes in the economy.[28] Restricting the population in this way brings the analytic sample to 4,427 teacher-year observations (from 25,291 observations in the general dataset). In this analytic sample, 33% of teachers have four years of service in year j, making them targeted for the retention bonus.

[28] Note that teachers with 3-5 years of service in SFUSD can have only 1-2 years or more than 16 years of total teaching experience, since the years of service variable captures experience in any role in SFUSD; teachers could have moved into teaching from another role in SFUSD, or moved to SFUSD from teaching elsewhere.

In this model, I test several additional specifications. First, as discussed above, I test a varied definition of the implementation period to see if there was an effect in 2008-09 or a varied effect in 2009-10 or 2010-11. Second, I test for an effect when I limit the sample to hard-to-staff schools. Finally, I expand the sample to simultaneously test for an effect of the retention bonus on 4th and 8th year teachers in year j. As discussed above, 8th year teachers are not well identified for this bonus, so they are excluded from the main specification, but I include them in a specification to examine potential impacts for the whole group.[29]

Hard-to-staff school bonus. A simple look at descriptive statistics shows that hard-to-staff schools have higher turnover both before and after QTEA, but that retention improves for hard-to-staff schools more after QTEA. As shown in Table 6, rates of in-school retention are lower in hard-to-staff schools both before and after QTEA (72% and 80%, respectively), compared to non-hard-to-staff schools (83% and 87%, respectively). Furthermore, return rates in hard-to-staff schools increased dramatically after QTEA; the pre-post QTEA difference in hard-to-staff schools is 8 percentage points, whereas this difference is only 3 percentage points in non-hard-to-staff schools.

While the increase in retention rates in hard-to-staff schools seems to suggest a QTEA effect, this observed change cannot be attributed to QTEA. Hard-to-staff schools would be more affected by the economy than non-hard-to-staff schools; because these schools had higher turnover before the economic downturn, retention increases as a result of the economy would differentially benefit hard-to-staff schools. Thus, a simple means comparison (as shown in Table 6) conflates the changes in the economy with the introduction of the hard-to-staff school bonus.

[29] When I test the effect for the 4th and 8th year teachers simultaneously, and include teachers with three to nine years of service in SFUSD in year j, the number of teacher-year observations is 15,608.

To isolate the effect of hard-to-staff school bonus, I employ a matching strategy to investigate whether the retention rate in hard-to-staff schools increased relative similar schools. My goal in matching is to create a comparison group of schools that are similar to the schools designated hard-to-staff in all ways except for the fact that some received the designation. By reducing the sample in this way, the difference-in-differences approach isolates the "QTEA effect."

The basic strategy I employ is a propensity score match (Caliendo & Kopeinig, 2008), where I match hard-to-staff schools with non-hard-to-staff schools that have a similar probability of selection.[30] To create these matches, I first reduced the dataset (which included 119 schools and 25,291 teacher-year observations to start), dropping alternative schools and schools that were not operational both before and after QTEA. Then, I retained only observations in years 2005-06, 2006-07, and 2007-08; this is because hard-to-staff schools were initially designated prior to the 2009-10 school year, so it is likely that school characteristics in the years immediately prior best predict which schools were chosen as "hard-to-staff." Again I limit the sample to teachers with 3-16 years of experience on the salary schedule and those with more than 2 years of service within SFUSD in year j, as these teachers could be targeted for layoffs and thus their retention behaviors would be impacted by the economic changes. This restricted pre-QTEA sample includes 4,975 teacher-year observations in 96 schools. This sample was used to generate average within-school return rates, and then the dataset was reduced again to one observation per

[30] Recall that the list of hard-to-staff schools changed slightly for the 2010-11 school year (4 schools were redesignated). I define "hard-to-staff" schools as those that were initially designated and match them to comparable schools.

school (96 observations). I then used Equation 5 (a linear probability model) to predict each school's probability of being initially selected hard-to-staff:[31]

(5) $$\Pr(Y_s = 1) = \beta_o + \beta_1 API_s + \beta_2 \operatorname{Re} turnRate_s + \beta_3 Elem_s + \beta_4 HS_s$$

where the outcome (a school *s*'s initial selection as a hard-to-staff school) is a linear function of *API* (the school's average API base score in the time period, which is the state of California's school-level performance metric ranging from 200 to 1000), *ReturnRate* (the school's average annual teacher return rate over the same time period for teachers with 3-16 years of experience), and *Elem* and *HS,* which are indicators for school level (β_0 in this model represents K-8 and Middle Schools). (The R-squared on this model is 0.4711, indicating that school characteristics do not perfectly predict selection, which is promising for establishing a matched comparison group). I then predicted each school's probability of being initially selected as a hard-to-staff school. Non-hard-to-staff schools and hard-to-staff schools were matched if they were adjacent in this probability sorting. This produces an analytic sample with 16 hard-to-staff schools and 14 matches. This matched group includes eight elementary schools and eight matches, three middle schools and two matches, and five high schools and four matches.[32]

As shown in Table 7, the hard-to-staff schools are similar to the non-hard-to-staff schools in the matched group on observable characteristics. The average within-school return rate for both the hard-to-staff schools and the non-hard-to-staff schools is 79% in the pre-QTEA time period. There is no statistically significant difference in the average API base scores, the average API rank (a quintile rank of achievement assigned by the California Department of Education to

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[31] Note, I tried many different matching strategies, including specifications that included many more predictor variables and additional years of pre-QTEA implementation data. None of the models produced matches that were better than the model specified above (in terms of the similarity of the schools designated hard-to-staff and not-hard-to-staff).

[32] Note that in the sample, 4 of the matched elementary schools became hard-to-staff schools in 2010-11, and 3 schools designated hard-to-staff in 2009-10 lost the designation in 2010-11 (one elementary school and two K-8 schools).

the state's schools), or the average percent of students eligible for Free and Reduced Price Lunch or classified as English Learners.

[Insert Table 7 here.]

When I only include teachers with 3-16 years of experience (and 3 or more years of service in SFUSD) in these matched schools, and retain only observations after 2005,[33] the analytic sample is reduced to 2,672 teacher-year observations, with 55% in hard-to-staff schools. Using this matched sample, I test whether teachers in "hard-to-staff" schools have higher retention rates than their matched counterparts. Because the schools are selected to be similar except for that some were targeted by QTEA, any increases in hard-to-staff schools relative to non-hard-to-staff schools can be attributed to QTEA. I also include several additional specifications. Because of the complications regarding the reclassification of schools as hard-to-staff, I include a specification in which I test for varied effects using 2009-10 and 2010-11 as separate variables, and I include a specification in which I only observe retention behavior of teachers in schools whose designation remained the same over the entire time period.

Measuring effectiveness increases after QTEA

To investigate whether there was a differential effect of QTEA for highly-effective teachers, it would be ideal to conduct the three analyses specified above and to include measures of effectiveness in the model. This approach would allow me to study whether the retention of highly-effective teachers is higher after QTEA and whether those highly-effective teachers who are also targeted for salary increases have higher return rates than others. However, due to statistical power issues, such an analysis is not possible at this time. The analytic samples to study the effect of the three salary interventions must be greatly reduced to isolate a causal effect

[33] Years prior to 2005 must be excluded, as the school matches are not similar in observable characteristics beyond this time point.

of QTEA.[34] Furthermore, as shown in Table 5, only 19% of teachers have either a value-added score in ELA or Mathematics, which reduces the sample size for this analysis even further. Thus, while an analysis investigating the effects of QTEA for highly-effective teachers who are also targeted by salary incentives may be possible in several years, at this time (after only two full years of implementation), the data does not support such an analysis.

Given the limitations of the data at this time, a way to investigate this question is to observe average return-rates for teachers at varying levels of effectiveness before- and after QTEA. A positive finding here would not show a causal effect of QTEA, however it might suggest that QTEA has been effective in retaining highly-effective teachers. On the other hand, a null effect would show that there is likely no "QTEA effect" for the highly-effective teachers; if an overall effect cannot be detected, it seems unlikely that there is a differential effect for highly-effective *targeted* teachers.

To answer this question, I use a similar model to the multinomial logit model employed above study whether the retention rates for highly-effective teachers are different after QTEA:

$$(6) \qquad P_{ij+1}^{h} = \frac{\exp(\beta_0^h + \beta_1^h E_{ij} + \beta_2^h QTEA_{j+1} + \beta_3^h E_{ij} * QTEA_{j+1} + \beta_4^h SIG_{j+1})}{\sum_{g=1}^{G} \exp(\beta_0^g + \beta_1^g E_{ij} + \beta_2^g QTEA_{j+1} + \beta_3^g E_{ij+1} * QTEA_{j+1} + \beta_4^g SIG_{j+1})}$$

In this model, the probabilities of leaving the district in the next year (h=1), returning to the same school the next year (h=2), or remaining in the district and transferring to another SFUSD school the next year (h=3) are a function of teachers effectiveness (*E*), whether the year in question is in the QTEA implementation period (*QTEA*), and the interaction of the teacher's effectiveness with the QTEA implementation period (*E*QTEA*). Again, the identification of SIG schools in 2010-11 is included as a control. Here I am interested in whether more highly-

[34] The number of teacher-year observations is 14,277, 4,427, and 2,672 for overall salary increase, the retention bonus, and the hard-to-staff school bonus, respectively.

effective teachers both stayed in their schools and stayed in the district (transferring schools) after QTEA compared to leaving; thus I use "leaving the district" (h=1) as the base scenario in these models. Here, a QTEA effect would be indicated by increases in both the rates of staying in schools and transferring for the highly-effective teachers relative to leaving the district.

I use the value-added scores detailed above to define teachers as either "highly-effective" or "less-effective", placing half of the teachers in each year, grade, and subject in each category This strategy removes some of the variability in scores associated with teacher-by-year value-added scores (Atteberry, 2011; Koedel & Betts, 2007; McCaffrey, et al., 2009), hopefully better identifying teachers who are more effective. The analytic sample for this question includes all teachers with value-added scores; 4,878 teachers in ELA, and 4,745 teachers in Math, with 50% of teachers in each subject in each effectiveness category.

Once again, further analysis is required to understand the coefficient of interest. Here, the calculation of the marginal effect tests whether there is a difference between highly-effective and less-effectiven teachers in the difference in retention rates before and after QTEA:

(7) *[Return rate(High-E, Post-QTEA) – Return rate(High-E, Pre-QTEA)]*
– [Return rate(Low-E, Post-QTEA) – Return rate(Low-E, Pre-QTEA)]

Results

Retention effects

A first look into the effect of QTEA on teacher retention in SFUSD is to observe return behavior for all teachers before and after implementation of the policy. Such an approach is not causal but tells us generally if retention changed in the period after QTEA implementation. Table 8 presents the results of the multinomial logit model (Equation 2) as relative risk ratios, with leaving the district as the reference group). These results indicate that after QTEA, a teachers' likelihood of staying in his or her school increases by a factor of 1.56 relative to leaving.

Similarly, a teachers' likelihood of staying in the district but transferring schools increases by a factor of 1.32 relative to leaving. This is the pattern that we would hope to see if QTEA has had an effect: teacher within-school retention improves, and those that are unhappy at their school site are more likely to transfer to another school within SFUSD rather than leave the district. However, for causal interpretations, I must isolate the QTEA effect by comparing the change in retention behavior for teachers who are "targeted" for each of the salary interventions compared to those who are not targeted.

[Insert Table 8 here.]

Overall salary increase. To investigate the extent to which retention improves as a result of QTEA's overall salary increases, I compare the change in retention behavior of "targeted" teachers and "non-targeted" teachers. As discussed above, I limit the sample to teachers who have 3-16 years of teaching experience and more than two years of service within SFUSD in order to isolate the effect for targeted teachers.

Table 9 displays the results of the multinomial logit regressions, where "leaving the district" (h=1) is modeled as the base scenario. Recall that a QTEA effect would be indicated by increases in the probability of targeted teachers both staying in schools and transferring relative to leaving the district. Model 1 displays the results of the basic model in relative risk ratios. The 0.601 relative risk ratio for targeted teachers in the "Stay" column indicates that prior to QTEA, teachers who would be targeted were less likely to stay in their school relative to leaving the district than were non-targeted teachers. The second column ("Transfer") shows that these teachers were also less likely to transfer than to leave. The increased leaving behavior of these targeted teachers may be because they were relatively less experienced. The second coefficient in the basic model shows that after QTEA all teachers were less likely to leave the district. In the

QTEA period teachers were approximately twice as likely to stay in their school and just under twice as likely to transfer relative to leaving than before the policy. This increased district retention is likely due, at least in part, to the economic downturn as described above.

The third coefficient in the basic model is the one of particular interest for this paper. It measures the extent to which targeted teachers were more likely to stay in their school relative to leaving the district post-QTEA in comparison to non-targeted teachers.[35] These coefficients are not statistically different than zero, providing an indication that targeted teachers do not respond differently to QTEA than non-targeted teachers. However, as discussed above, the difference-in-differences estimator requires additional calculations. Using Equation 4, the difference-in-differences estimator indicates that the "QTEA effect" for teachers targeted for overall salary increases was an increase in rates of staying in the same school of 1.2 percentage points and a decrease in the transfer rates of 0.3 percentage points (neither is significant).[36]

[Insert Table 9 here.]

I includeda number of additional tests to investigate whether a QTEA effect could be detected under different model specifications. Full results appear in Table 9; in what follows, I discuss only the marginal effect estimating the difference-in-differences coefficient. Model 2 provides a specification that separates the implementation years: 2008-09, 2009-10, and 2010-11. (See Appendix A for the equation.) The goal is to test whether there was a retention effect in 2008-09 (a partial implementation year) and to test for varied effects in 2009-10 (the first full year of implementation) and 2010-11. In the 2008-09 school year, there was no retention effect for targeted teachers; in that year (compared to pre-QTEA), the return rate to schools was 0.1

[35] If significant, this coefficient would indicate that the effect for QTEA for the targeted teachers is 0.84 times the effect of QTEA for the non-targeted teachers.
[36] The 95% confidence interval on this estimate ranges from -0.017 to 0.042, suggesting that there is no QTEA effect, but also that a large effect can be ruled out.

percentage points lower for targeted teachers than for non-targeted teachers, and the transfer rate (staying in the district) was 1.3 percentage points higher (neither estimate is significant). However, in the 2009-10 school year, there seems to have been a retention effect for targeted teachers; in that year, the return rate to schools was higher by 4.5 percentage points compared to pre-QTEA, and the transfer rate (staying in the district) was unchanged (1.1 percentage point lower, but not significant).[37] I am able to detect a significant marginal effect for 2009-10 even when multiplicative effects are not significant; this is consistent with the properties of calculating marginal effects in multinomial logit model (Buis, 2010). In the 2010-11 school year, there was no retention effect for targeted teachers; in that year, the return rate to schools was 2.1 percentage points lower for targeted teachers than for non-targeted teachers, and the transfer rate (staying in the district) was 0.8 percentage points higher (neither estimate is significant).[38] The effect for 2009-10 is represented visually in Figure 5. This result is encouraging, and the effect in 2009-10 and not 2010-11 could be explained by the uncertainty around the use of the QTEA funds for the 2010-11 school year. However, this one positive effect among a group on null effects may simply be an anomaly and not indicative of a true QTEA effect.

[Insert Figure 5 here.]

Next, I test whether there is an effect specifically in the schools designated "hard-to-staff." As shown in Table 6, such schools have lower retention rates both before and after QTEA, and thus this is a population that we might expect would be differentially affected by the policy. Model 4 presents the results; the difference-in-differences estimator indicates there is still no

[37] The 95% confidence interval on this estimate ranges from 0.009 to 0.082; this estimate does not include zero, suggesting a true positive effect. However, the range also suggests that a low value (0.9 percentage points increase in within-school retention) is possible.

[38] Note that the differences are calculated by comparing teachers in the target year to the time period before QTEA, holding the other years at 0. Thus, to isolate the 2009-10 effect, I use Equation 2.4, where "Post-QTEA" represents the 2009-10 school year, and "Pre-QTEA" represents the time period 2002-03 to 2007-08.

QTEA effect within these schools; there is not a significant change in the retention rates of targeted teachers in schools or transfer rates within the district.

Finally, I test a specification in which I limit the sample to teachers with 4-11 years of experience. Model 4 presents the results; the difference-in-differences estimator indicates there is still no QTEA effect for teachers in this more restricted range of experience; there is not a significant change in the retention rates of targeted teachers in schools or transfer rates within the district.[39]

Retention bonus. To investigate the extent to which retention improves for teachers as a result of the retention bonus, I compare the changes in retention behavior of targeted and non-targeted teachers before and after QTEA. Table 10 displays the results of the multinomial logit regressions, where "leaving the district" (h=1) is modeled as the base scenario. (Recall that a QTEA effect would be indicated by increases in the probability of targeted teachers both staying in schools and transferring relative to leaving the district.) Model 1 displays the results of the basic model in relative risk ratios (limiting to teachers with 3-5 years of service in SFUSD in year j). The 0.915 relative risk ratio for targeted teachers in the "Stay" column indicates that prior to QTEA, teachers who would be targeted were as likely to stay in their school relative to leaving the district as were non-targeted teachers. The second column ("Leave") shows that these teachers were also as likely to transfer as to leave. (This coefficient provides an indication that the non-targeted teachers are a good comparison group for the targeted teachers, since they

[39] Note, there were many other specifications tried and not included here because none of the investigations produced varied results. Such investigations include: including teacher experience and experience squared (both interacted with QTEA); dropping salary schedules on which teachers are not targeted at all to control for the fact that some teachers are not targeted because they have low levels of education (which may make those teachers different from those on salary schedules that are targeted); using a continuous indicator of QTEA salary increases to determine targeted teachers instead of the binary indicator. More generally, I also tested whether there was a differential effect for teachers in hard-to-fill subjects, in various school levels, in schools designated hard-to-staff in either 2010 or 2011, and restricting the sample to non-alternative schools that were open during the entire time period in question.

have the same retention rates prior to QTEA.) The second coefficient in the basic model shows that after QTEA all teachers were less likely to leave the district. In the QTEA period teachers were 1.3 times more likely to stay in their school, but were as likely to transfer relative to leaving than before the policy. This increased within-school retention is likely due, at least in part, to the economic downturn as described above. The third coefficient in the basic model is the one of particular interest for this paper. It measures the extent to which targeted teachers were more likely to stay in their school or transfer relative to leaving the district post-QTEA in comparison to non-targeted teachers.[40] These coefficients are not statistically different than zero, providing an indication that targeted teachers do not respond differently to QTEA than non-targeted teachers. However, as discussed above, the difference-in-differences estimator requires additional calculations. Using Equation 4, again there is no detectable QTEA effect; the difference-in-differences estimator indicates that the "QTEA effect" for teachers targeted for overall salary increases was an increase in rates of staying in the same school of 2.2 percentage points and a decrease in the transfer rates of 0.1 percentage points (neither is significant).[41]

[Insert Table 10 here.]

I included a number of additional tests to investigate whether a QTEA effect could be detected under different model specifications. Full results appear in Table 10; in what follows, I discuss the marginal effect estimating the difference-in-differences. Model 2 provides a specification that separates the implementation years 2008-09, 2009-10, and 2010-11. In this specification, there is no detectable "QTEA effect" in any year.

[40] If significant, this coefficient would indicate that the effect for QTEA for the targeted teachers is 1.15 times the effect of QTEA for the non-targeted teachers.
[41] The 95% confidence interval on this estimate ranges from -.030 to 0.074, suggesting that there is no QTEA effect, but also that a large effect can be ruled out.

However, it does appear there was an effect in the schools designated "hard-to-staff." As shown in Model 3, the difference-in-differences estimator indicates that in hard-to-staff schools after QTEA the within-school retention rate is 15 percentage points higher for teachers targeted by the retention bonus than it would have been in the absence of QTEA.[42] Figure 6 presents this finding visually.[43] While this finding is encouraging, it should be interpreted with caution. While the retention rate does increase substantially, the improvements in QTEA retention rate seem implausibly large, especially given the mostly null effects demonstrated thus far. However, there is a substantial sample size for this analysis,[44] and findings are robust to various specifications.[45]

[Insert Figure 6 here.]

Hard-to-staff school bonus. Here I test the effect of the hard-to-staff school bonus on improving teacher retention in targeted schools. I use the basic equation specified in Equation 3, where *TARGETED* indicates whether teachers were in a school initially designated hard-to-staff. In this model, "returning to the same school" (h=2) is modeled as the base scenario. (Recall that a QTEA effect would be indicated by decreases in the probability of targeted teachers both leaving the district and transferring relative to staying in their school.) Model 1 in Table 11 displays the results of the basic model in relative risk ratios. The 1.103 relative risk ratio for targeted teachers in the "Leave" column indicates that prior to QTEA, teachers in hard-to-staff

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[42] The 95% confidence interval on this estimate ranges from 0.045 to 0.247, suggesting that there is there is a substantial to large QTEA effect.

[43] Note, there were many other specifications tried and not included here because none of the investigations produced varied results. Such investigations include: including teacher experience and experience squared (both interacted with QTEA); testing whether there was a differential effect for teachers in hard-to-fill subjects, in various school levels, in schools designated hard-to-staff in either 2010 or 2011, and restricting the sample to non-alternative schools that were open during the entire time period in question.

[44] The Ns were as follows for this analysis: 663 teachers were in the non-targeted group pre-QTEA, 262 teachers were in the non-targeted group post-QTEA, 324 teachers were in the targeted group pre-QTEA, and 109 teachers were in the targeted group post-QTEA.

[45] I tested, but did not include here, specifications including all 29 schools ever identified hard-to-staff and a larger sample of the district's highest turnover schools, which includes all the schools ever designated hard-to-staff and the additional schools identified as matches. All specifications show a QTEA effect on improving within-school retention rates for targeted teachers.

schools were as likely to leave the district (relative to staying in their school) as were teachers in the matched non-hard-to-staff schools. The second column ("Stay") shows that these teachers were also as likely to transfer as to stay. (This provides an indication that the matched schools provide a good comparison for the hard-to-staff schools, since retention rates were the same for the two groups before QTEA.) The second coefficient in the basic model shows that after QTEA all teachers were less likely to leave the district. In the QTEA period teachers were 0.70 times as likely to leave the district (but were as likely to transfer) relative to staying than before the policy. This increased within-school retention is likely due, at least in part, to the economic downturn as described above. The third coefficient in the basic model is the one of particular interest for this paper. It measures the extent to which targeted teachers were more likely to stay in their school relative to leaving the district post-QTEA in comparison to non-targeted teachers.[46] These coefficients are not statistically different than zero, providing an indication that targeted teachers do not respond differently to QTEA than non-targeted teachers. However, as discussed above, the difference-in-differences estimator requires additional calculations. Using Equation 4, the difference-in-differences estimator indicates that there was no "QTEA effect" in hard-to-staff schools; there was a decrease in rates of leaving the district of 0.4 percentage points for targeted teachers[47] and an increase in the transfer rates of 0.9 percentage points (neither estimate is significant).

[Insert Table 11 here.]

I included a number of additional tests to investigate whether a QTEA effect could be detected under different model specifications; full results appear in Table 11. Model 2 provides a

[46] If significant, this coefficient would indicate that the effect for QTEA for the targeted teachers is 0.99 times the effect of QTEA for the non-targeted teachers.
[47] The 95% confidence interval on this estimate ranges from -0.049 to 0.041, suggesting that there is no QTEA effect, but also that a large effect can be ruled out.

specification that separates the implementation years 2008-09, 2009-10, and 2010-11. In this specification, there is still no detectable "QTEA effect." In Model 3, to test whether the redesignation of schools in 2010-11 could be interfering with my ability to estimate a QTEA effect, I include a specification in which I exclude schools whose designation changed between 2009-10 and 2010-11. Again, I find no QTEA effect. This pattern of results suggests that, while retention rates increased dramatically in hard-to-staff schools after QTEA (as demonstrated in Table 6), it does not appear that any part of this retention increase can be attributed to QTEA's hard-to-staff school bonus.[48]

Exploring the relationship between retention and teacher quality

The results presented above show that there has been little overall effect of QTEA's salary increases. Yet it is still useful to investigate changes in retention behavior for highly-effective after QTEA. Table 12 displays the results of the multinomial logit regressions (in relative risk ratios), where "leaving the district" (h=1) is modeled as the base scenario. (While this is not a causal analysis, a QTEA effect would be suggested by increases in the probability of highly-effective teachers both staying in schools and transferring relative to leaving the district after QTEA.) The results in Table 12 show that highly-effective teachers have higher retention rates, but that they do not seem to have been differentially affected by QTEA. In ELA, the 1.40 relative risk ratio for teacher effectiveness in the "Stay" column indicates that prior to QTEA, highly-effective teachers were 1.40 times more likely to stay in their school relative to leaving the district than were less effective teachers. The second column ("Leave") shows that these teachers were slightly less likely to transfer than to leave the district. This same pattern holds for

[48] Note, there were many other specifications tried and not included here because none of the investigations produced varied results. Such investigations include: including teacher experience and experience squared (both interacted with QTEA); testing whether there was a differential effect for teachers in hard-to-fill subjects, and in various school levels.

Math; highly-effective teachers are 1.44 times more likely to stay in their school relative to leaving the district than are less effective teachers (and as likely to transfer as to leave).

The second coefficient shows that all teachers were more likely to stay in their schools after QTEA. In the QTEA period teachers were 1.39 times more likely to stay in their school in the ELA sample and 1.57 times more likely in the Math sample. (In both the ELA and Math samples, teachers were as likely to leave the district as to transfer.) The third coefficient in the basic model is the one of particular interest for this paper. It measures the extent to which highly-effective teachers were more likely to stay in their school or transfer within SFUSD relative to leaving the district after QTEA.[49] These coefficients are not statistically different than zero, providing an indication that highly-effective teachers did not respond differently to QTEA than less effective teachers. However, as discussed above, the difference-in-differences estimator requires additional calculations. Using Equation 4, the difference-in-differences estimator indicates that there was no "QTEA effect;" in ELA after QTEA, there was a decrease in rates of highly-effective teachers staying in the same school of 1.8 percentage points and an increase in the transfer rates of 0.5 percentage points (neither is significant). In Math, these numbers are 0.2 percentage points and 0.3 percentage points, respectively (again not significant).

[Insert Table 12 here.]

Consistent with prior literature (Boyd, et al., 2011; Goldhaber, et al., 2007; Hanushek & Rivkin, 2010; Krieg, 2006), I find that highly-effective teachers (in both ELA and Math) are more likely to return to their schools the next year than their less effective peers. Furthermore, I find that return rates of both groups increases after QTEA, but that there is no differential effect for highly-effective teachers after QTEA. This pattern of within-school retention is presented

[49] If significant, this coefficient would indicate that the effect for QTEA for the targeted teachers is 0.85 times the effect of QTEA for the non-targeted teachers in ELA, and 1.40 times the effect of QTEA for the non-targeted teachers in Math.

visually in Figure 7. In both ELA and Math, the within-school return rates are higher after QTEA for both high- and low-effectiveness teachers. While within-school retention rates increase for all teachers after QTEA, there does not seem to be a differential effect for highly-effective teachers in either ELA or Math. In ELA, the within-school return rate for the less effective teachers goes from 83-87%, and for highly-effective teachers from 88-91%. In Math, the within-school return rate for less effective teachers goes from 83-88% and for high-effectiveness teachers from from 88-93%.

[Insert Figure 7 here.]

I have demonstrated that there is no differential effect for highly-effective teachers overall after QTEA, thus it is highly unlikely that I would be able to detect a differential effect of salary and bonuses for highly-effective teachers. Furthermore, given the (mostly) null results overall presented in Table 9, Table 10, and Table 11, it seems likely that further analysis attempting to measure a differential impact on highly-effective teachers who are targeted by QTEA's salary increases would yield additional null results at this time.

Conclusions and reflections on QTEA's Effect on Teacher Retention

QTEA introduced moderately-sized overall salary increases targeted toward early-career teachers, retention bonuses for teachers after their 4th and 8th year of service in SFUSD, and bonuses for teachers in hard-to-staff schools. A simple analysis of retention behavior before and after QTEA shows that teachers were 1.4 times more likely to stay in their schools after QTEA and 1.2 times more likely to transfer to another school within SFUSD rather than leave the district (Table 8). However, such a simple analysis does not estimate a causal effect of QTEA's salary incentives. Many things changed at the same time as QTEA implementation, most namely the economy, in which the unemployment rate went from 5.6% to 9.6% in the first year of QTEA implementation. Thus, to separate the effect of QTEA from other secular trends, I investigate the effects of these bonuses in three separate difference-in-differences models that compare changes in the retention behavior of targeted teachers and non-targeted teachers.

Overall, the pattern of results shows that QTEA had a minor (if any effect). Of many tests, I find only two significant findings: 1) Teachers targeted for overall salary increases had higher retention rates to their schools *only in the first year of QTEA implementation* (2009-10); 2) Teachers targeted for the retention bonus had higher retention rates *only in hard-to-staff schools*. The first result can be found in Table 9: I estimate the within-school retention rate for teachers targeted by the overall salary increase to be 4.5 percentage points higher than it would have been in the absence of QTEA. The second result can be found in Table 10: I estimate the within-school retention rate for 4th year teachers in hard-to-staff schools to be 14.5 percentage points higher than it would have been in the absence of QTEA.

These results make intuitive sense. The fact that the overall salary increase was only effective in the first year of implementation could imply that the uncertainty around jobs and compensation in the 2009-10 school year limited teachers' response to QTEA in the 2010-11 school year. Even though the overall salary increases ultimately remained intact as part of the district and union's agreement, QTEA was "on the chopping block" and teachers were not sure that any part of QTEA would be fulfilled in the following year. Similarly, the fact that we might only detect findings in hard-to-staff schools makes intuitive sense; as I discussed above, teachers in such schools may be more responsive to compensation increases, both because their working conditions are more difficult and because retention in these schools is lower, leaving more room for improvement. However, these two results must be interpreted with caution. The full pattern of findings suggests a null effect, and the presence of these two significant findings may simply be an anomaly and not indicative of a true QTEA effect. The limited findings, and the fact that findings are not robust across specifications or models, suggests that teachers in SFUSD have not uniformly responded to QTEA's compensation increases by remaining in their schools or in the district. Combining lessons from this analysis and survey research, I will explore some possible reasons for the limited effect.

In a time of economic downturn, teacher retention may not be the right goal

First, and most importantly, it is possible that teacher retention is not the right goal in a time of economic downturn. As shown in Table 8, the within-school retention rate in SFUSD before QTEA was 80%, and the within-district retention rate was 87%; after QTEA these numbers increased to 85% and 91%, respectively. This increase in retention (which I assume is mostly related to economic changes, since my attempts to isolate QTEA's compensation changes produced mostly null results), leaves little room for QTEA to have an effect.

Furthermore, as I show in Figure 7, within-school retention rates are higher for highly-effective teachers and reach very high rates after QTEA: 94% for highly-effective teachers in ELA and 91% for highly-effective teachers in Math. With retention rates above 90% for highly-effective teachers, it would be difficult for any policy to raise this retention rate substantially. In addition, this finding suggests that if less effective teachers are the ones leaving, perhaps this turnover is a good thing for schools. Indeed, institutional turnover can be a good thing, resulting in better person-job matches and refreshing a faculty with new ideas and energy (Abelson & Baysinger, 1984).

It is possible that when the economy improves and teachers have more options (to transfer to other schools and districts, and to obtain jobs in other fields), retention may again become a problem, in which case retention may again be an important goal and QTEA could have an impact. However, in this policy climate, the possible effect of compensation increases on teacher recruitment is limited.

Policy implementation

Another potential factor limiting effects is policy implementation problems. As discussed above, there was major budgetary distress in SFUSD in the 2009-10 school year, and teachers were not sure if there would be jobs in 2010-11, much less if QTEA's salary incentives would be fulfilled. In the end, the overall salary increases and the hard-to-staff school bonus remained intact, and the retention bonus was reduced by half for the 2010-11 and 2011-12 school years. Such uncertainty about QTEA could certainly interfere with teachers' response to the policy. This is a problem that is not unique to SFUSD; urban school districts tend to pursue policy solutions in a start-and-stop, chaotic fashion that impedes impact (Hess, 1998). This "policy churn" is related to both changes in goals and leadership and budget uncertainty, as state funds are reduced dramatically and in ways that school districts cannot predict (Balu, 2011).

In addition, the identification of teachers who received the retention bonus was not clear or consistent, and (by district report) many teachers who initially should have gotten bonuses did not. Indeed, my identification of teacher years of service in SFUSD indicates that only 65% of the teachers who should have gotten the retention bonuses after their 4th year of teaching actually did. This could make the bonus receipt seem random to teachers, which could limit the impact of the bonuses on teacher retention. This is another kind of uncertainty that can dramatically interfere with the potential effects of the policy (Honig, 2006).

Teacher information

It also seems that information about the salary incentives could play a mediating role. If the theory of action in such interventions is that teachers receive salary and bonus and respond accordingly (by not leaving the system), it is important that teachers *know about* the monetary incentives (Holtmann, 1969; Honig, 2006; McCall, 1970; Rees, 1966; Stigler, 1961, 1962).[50] To explore this mechanism in San Francisco, in the 2010 survey, I asked teachers if they expected to receive bonuses in that school year. As shown in Figure 8, while 96% of teachers who received the hard-to-staff school bonus were aware of it, only 69% of teachers who received the retention bonus in that year reported awareness of having received it. In addition, I asked teachers if they were familiar with QTEA's salary provisions; only 52% reported that they were familiar (41% reported some familiarity, and 6% reported no familiarity).

[Insert Figure 8 here.]

I also asked teachers how much money they expected to receive as a result of QTEA's bonuses in the 2009-10 school year.[51] As shown in Figure 9, 17% of teachers who received a bonus reported that they did not know the amount, 53% of teachers' estimates are within $1,000 of the actual amount they received, 22% think they received more than $1,000 less than they actually did, and 10% think they received more than $1,000 more. The real concern here is the 39% of teachers who either do not know or think they are getting $1000 or less than they actually are. These teachers are unlikely to respond in the desired way, since they are not fully aware of the bonus payments that *they actually received*.

[Insert Figure 9 here.]

[50] In recent work, Clotfelter, Glennie, Ladd and Vigdor (2008a, 2008b) investigate how teacher information about bonuses might affect their response to an $1,800 retention bonus. They report that many principals and teachers did not know about the bonuses, and that this lack of awareness likely was a major reason why the bonuses did not have the desired effect on retention.
[51] Note this estimate includes the retention bonus, the hard-to-staff school bonus, and the hard-to-fill subject bonus, which is not covered in this paper; it does not include the overall salary increase.

Compensation increases are not enough

As discussed above, the theory of salary interventions like QTEA is that the additional compensation is enough to provide a "compensating differential" for characteristics of the job that may be undesirable. Thus, one possible explanation of a null effect is that the additional compensation is not enough to make teachers want to trade off on the other job characteristics that they prefer.

Part of QTEA's goal in raising salaries was to make SFUSD's compensation more attractive compared to neighboring school districts and other professions. While QTEA did make salaries more competitive with surrounding districts (see Table 2), I asked teachers how competitive they thought teacher salaries were in SFUSD compared to the past to gauge how they perceived QTEA's compensation increases. As shown in Figure 10, even teachers who are familiar with QTEA do not report that salary and bonus made the salaries more competitive. Of the 52% of teachers that reported familiarity with QTEA, only 31% of teachers believed that SFUSD's salaries were more competitive than before. This provides some indication that QTEA's salary increases may not have been high enough to provide that "compensating differential" that would entice more teachers to stay.

[Insert Figure 10 here.]

Overall, the findings in this paper suggest that QTEA's salary increases have not been effective in raising teacher retention rates either within schools or district-wide. However, the research questions in this paper may need to be revisited in several years. QTEA is a 20 year policy, and I have attempted here to detect a very short-term effect (the first two years of implementation) in a very turbulent economic time. In several years, when (presumably) the economy has improved, the uncertainty around QTEA's implementation has subsided, and the district has corrected early implementation problems, perhaps QTEA can be more effective in improving teacher retention.

Tables

Table 1. SFUSD compared to local school districts on various metrics

	Percent in SFUSD	SFUSD percentile compared to other local districts
Students who are English Learners	30.5%	76
Students eligible for Free or Reduced Price Lunch	55.5%	83
Schools in deciles 1-3 of performance statewide	38.5%	83
Students not proficient in English Language Arts	43.6%	69
Students not proficient in Math	39.2%	53
Teachers lacking full credentials	4.9%	75
Teachers with 1-2 years of experience	6.5%	79

Source: Analysis of Ed-Data files (www.ed-data.k12.ca.us) for the 2008-09 school year. Includes the 186 public school districts in the Combined Statistical Area (CSA) of San Jose-San Francisco-Oakland.

Table 2. SFUSD salaries compared to local school districts, before and after QTEA

	2007-08		2009-10		Percent change	
District Name	Step 3	Step 10	Step 3	Step 10	Step 3	Step 10
San Francisco Unified	$47,370	$63,272	$54,400	$65,300	15%	3%
Oakland Unified	$43,012	$54,328	$43,765	$54,328	2%	0%
San Jose Unified	$53,740	$71,772	$53,740	$71,772	0%	0%
Palo Alto Unified	$61,068	$79,863	$62,595	$81,860	3%	3%

Source: District Salary Schedules for 2007-08 and 2009-10.
Note: Salary information at both Step 3 and Step 10 is for teachers with a BA plus 60 units of continuing education.

Table 3. Number of teachers in each year, with retention outcomes in the following year

Year	Stay in school	Leave the district	Transfer to other positions within SFUSD	N
SY 2002-03	78.64%	14.44%	6.93%	3,249
SY 2003-04	82.25%	13.30%	4.45%	3,031
SY 2004-05	76.56%	16.24%	7.20%	3,349
SY 2005-06	80.18%	11.67%	8.16%	3,188
SY 2006-07	81.73%	12.07%	6.20%	3,114
SY 2007-08	83.82%	10.53%	5.65%	3,097
SY 2008-09	87.59%	7.33%	5.08%	3,111
SY 2009-10	82.27%	10.79%	6.95%	3,152
Total	81.56%	12.09%	6.35%	25,291

Table 4. Percentage of teachers at various years of service receiving retention bonuses[52]

	2009-10		2010-11	
Years of service in SFUSD	Percent receiving a bonus	N	Percent receiving a bonus	N
4	2.88%	208	4.02%	199
5	65.69%	204	67.05%	173
6	1.08%	185	2.47%	162
7	10.94%	64	0.00%	143
8	0.53%	188	0.00%	46
9	45.45%	132	68.59%	156
10	17.69%	147	8.55%	117
11	1.40%	143	1.72%	116
12-21	0.23%	622	0.33%	608

Table 5. Percentage of teachers with value-added scores, by year

School Year	Has ELA score	Has Math score	Has Math or ELA score	N
SY 2002-03	17.67%	18.10%	22.56%	3,249
SY 2003-04	19.17%	19.83%	24.02%	3,031
SY 2004-05	18.87%	19.86%	24.16%	3,349
SY 2005-06	19.79%	20.51%	25.06%	3,188
SY 2006-07	19.46%	19.69%	24.34%	3,114
SY 2007-08	18.60%	19.05%	23.83%	3,097
SY 2008-09	18.23%	18.96%	23.05%	3,111
SY 2009-10	18.34%	18.31%	22.75%	3,152
Total	18.76%	19.29%	23.72%	25,291

Table 6. Retention patterns in hard-to-staff schools and non-hard-to-staff schools, before and after QTEA

Year	Stay in school	Leave the district	Transfer to other positions within SFUSD	N
Hard-to-staff schools				
Pre-QTEA	72.17%	18.52%	9.30%	4,848
Post-QTEA	79.98%	12.06%	7.96%	1,633
Non-Hard-to-staff schools				
Pre-QTEA	83.29%	11.23%	5.49%	14,180
Post-QTEA	86.65%	8.01%	5.33%	4,630
Total				
Pre-QTEA	80.46%	13.09%	6.46%	19,028
Post-QTEA	84.91%	9.07%	6.02%	6,263

[52] Note that nine of the teachers who are listed as having received the bonus in 2010 actually received the payment in 2011; they erroneously were not awarded the bonus in 2010 and so the bonus was awarded a year late.

Table 7. Observable characteristics of matched schools

	Non-HTS	HTS	T statistic	P-value
Within-school return rate	0.79	0.79	0.10	0.92
API base	677.88	656.79	0.86	0.39
API rank	3.07	2.44	0.98	0.33
% students eligible for Free/Reduced Lunch	62.13	67.61	-1.20	0.24
% students classified as English Learner	35.48	28.34	1.02	0.31

Table 8. Retention patterns before and after QTEA, formalized in multinomial logit model

	Stay	Transfer
QTEA implementation period		
QTEA-2010/2011	1.563***	1.324***
	(0.079)	(0.103)
Number	25,291	25,291
Controls		
SIG	X	X

p<0.10~, 0.05*, 0.01**, 0.001***

Table 9. Change in teacher retention behavior as a result of QTEA's overall salary increase

	Model 1: Basic model (comparing teachers with 3-16 years of experience)		Model 2: Varied implementation years		Model 3: Including only HTS schools		Model 4: Restricting years of experience (4-11 years)	
	Stay	Transfer	Stay	Transfer	Stay	Transfer	Stay	Transfer
Targeted teachers (overall salary)	0.601***	0.690***	0.610***	0.674***	0.668***	0.711*	0.676***	0.762**
	(0.039)	(0.071)	(0.042)	(0.075)	(0.075)	(0.123)	(0.052)	(0.093)
QTEA implementation period								
QTEA-2010/2011	2.160***	1.844***			2.595***	2.505***	2.332***	2.201***
	(0.227)	(0.261)			(0.506)	(0.623)	(0.331)	(0.381)
QTEA-2009			1.680***	1.132				
			(0.213)	(0.213)				
QTEA-2010			2.167***	1.592*				
			(0.302)	(0.305)				
QTEA-2011			2.467***	2.193***				
			(0.366)	(0.421)				
Targeted teachers (overall salary) after QTEA								
Targeted teachers (overall salary), QTEA-2010/2011	0.843	0.783			0.724	0.603	0.762	0.773
	(0.136)	(0.183)			(0.201)	(0.235)	(0.093)	(0.205)
Targeted teachers (overall salary), QTEA-2009			0.928	1.191				
			(0.189)	(0.371)				
Targeted teachers (overall salary), QTEA-2010			1.200	0.911				
			(0.286)	(0.325)				
Targeted teachers (overall salary), QTEA-2011			0.623*	0.703				
			(0.130)	(0.206)				
Number	14277	14277	14277	14277	3634	3634	9058	9058
Effect for targeted teachers (% increase in retention)								
QTEA-2010/2011	0.012	-0.003			0.010	0.014	0.004	-0.002
	(0.015)	(0.010)			(0.033)	(0.023)	(0.018)	(0.012)
QTEA-2009			-0.001	0.013				
			(0.021)	(0.013)				
QTEA-2010			0.045*	-0.011				
			(0.019)	(0.012)				
QTEA-2011			-0.020	0.008				
Controls			(0.021)	(0.014)				
SIG	X	X	X	X	X	X	X	X

p<0.10~, 0.05*, 0.01**, 0.001***

Table 10. Change in teacher retention behavior as a result of QTEA's retention bonus

	Model 1: Basic model (comparing teachers with 3-5 years of service)		Model 2: Varied implementation years		Model 3: Including only HTS schools		Model 4: Including teachers with 3-9 years of service	
	Stay	Transfer	Stay	Transfer	Stay	Transfer	Stay	Transfer
Targeted teachers (retention bonus)	0.915	0.986	0.893	1.038	0.519***	0.588~	0.976	1.055
	(0.106)	(0.171)	(0.110)	(0.190)	(0.095)	(0.160)	(0.086)	(0.141)
QTEA implementation period								
QTEA-2010/2011	1.290~	0.961			1.059	0.847	1.476***	1.455*
	(0.189)	(0.215)			(0.257)	(0.298)	(0.168)	(0.236)
QTEA-2009			1.344	1.010				
			(0.299)	(0.341)				
QTEA-2010			1.751**	0.971				
			(0.378)	(0.326)				
QTEA-2011			1.062	0.972				
			(0.196)	(0.270)				
Targeted teachers (retention bonus) after QTEA								
Targeted teachers (retention bonus), QTEA-2010/2011	1.147	0.985			2.956**	1.806	1.087	0.855
	(0.285)	(0.373)			(1.297)	(1.149)	(0.220)	(0.249)
Targeted teachers (retention bonus, QTEA-2009			1.091	0.620				
			(0.385)	(0.360)				
Targeted teachers (retention bonus, QTEA-2010			0.878	0.609				
			(0.302)	(0.351)				
Targeted teachers (retention bonus), QTEA-2011			1.479	1.291				
			(0.490)	(0.611)				
Number	4427	4427	4427	4427	1363	1363	8939	8939
Effect for targeted teachers (% change)								
QTEA-2010/2011	0.022	-0.010			0.146**	-0.024	0.019	0.014
	(0.027)	(0.017)			(0.052)	(0.033)	(0.019)	(0.013)
QTEA-2009			0.035	-0.029				
			(0.037)	(0.023)				
QTEA-2010			0.011	-0.019				
			(0.033)	(0.020)				
QTEA-2011			0.043	-0.008				
Controls			(0.037)	(0.026)				
SIG	X	X	X	X	X	X	X	X

p<0.10~, 0.05*, 0.01**, 0.001***

Table 11. Change in teacher retention behavior as a result of QTEA's hard-to-staff school bonus

	Model 1: Basic model (comparing teachers in HTS schools with matched schools)		Model 2: Varied implementation years		Model 3: Excluding schools whose HTS designation changed	
	Leave	Transfer	Leave	Transfer	Leave	Transfer
Targeted teachers (HTS)	1.103	0.953	1.158	0.931	1.142	1.028
	(0.180)	(0.191)	(0.226)	(0.221)	(0.209)	(0.247)
QTEA implementation period						
QTEA-2010/2011	0.703~	0.922			0.723	0.949
	(0.149)	(0.216)			(0.177)	(0.278)
QTEA-2009			0.822	0.709		
			(0.219)	(0.232)		
QTEA-2010			0.443*	0.821		
			(0.143)	(0.252)		
QTEA-2011			0.902	0.841		
			(0.240)	(0.266)		
Targeted teachers (HTS) after QTEA						
Targeted teachers (HTS), QTEA-2010/2011	0.986	1.135			1.079	1.406
	(0.272)	(0.353)			(0.339)	(0.522)
Targeted teachers (HTS), QTEA-2009			0.837	1.077		
			(0.299)	(0.476)		
Targeted teachers (HTS), QTEA-2010			1.404	1.112		
			(0.571)	(0.464)		
Targeted teachers (HTS), QTEA-2011			0.713	1.208		
			(0.249)	(0.492)		
Number	2672	2672	2672	2672	2672	2672
Effect for targeted teachers (% change)						
QTEA-2010/2011	-0.004	0.009			0.001	0.020
	(0.023)	(0.020)			(0.026)	(0.022)
QTEA-2009			-0.019	0.007		
			(0.032)	(0.026)		
QTEA-2010			0.014	0.006		
			(0.030)	(0.028)		
QTEA-2011			-0.033	0.015		
			(0.032)	(0.027)		
Controls						
SIG	X	X	X	X	X	X

p<0.10~, 0.05*, 0.01**, 0.001***

Table 12. Change in the retention behavior of highly-effective teachers, before and after QTEA

	ELA		Math	
	Stay	Transfer	Stay	Transfer
Teacher effectiveness	1.403**	0.738~	1.443*	0.989
	(0.168)	(0.132)	(0.253)	(0.271)
QTEA-2010/2011	1.369~	0.974	1.571***	1.159
	(0.243)	(0.249)	(0.189)	(0.212)
Teacher effectiveness, after QTEA-2010/2011	0.858	0.788	1.403	1.391
	(0.224)	(0.326)	(0.418)	(0.610)
Number	4878	4878	4745	4745
Differential retention for high-quality teachers	-0.018	0.005	0.002	0.003
	(0.022)	(0.014)	(0.021)	(0.014)

p<0.10~, 0.05*, 0.01**, 0.001***

Figures

Figure 1. QTEA implementation timeline

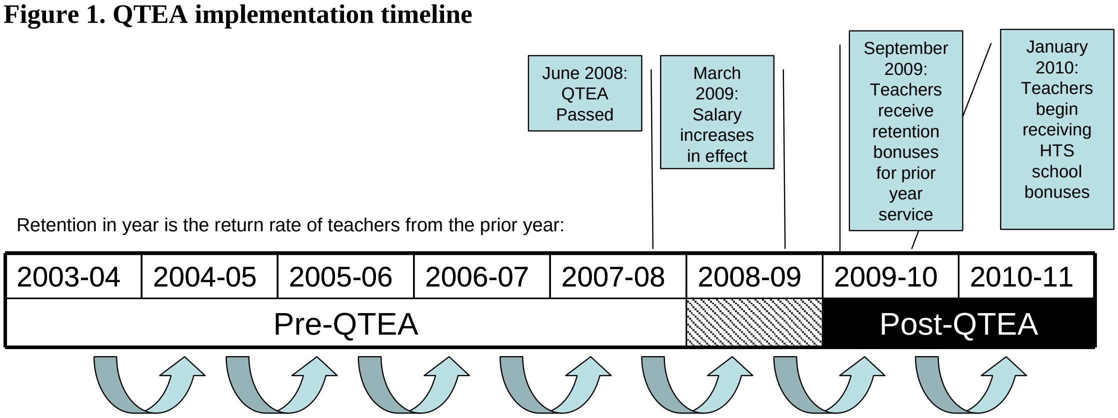


Figure 2.

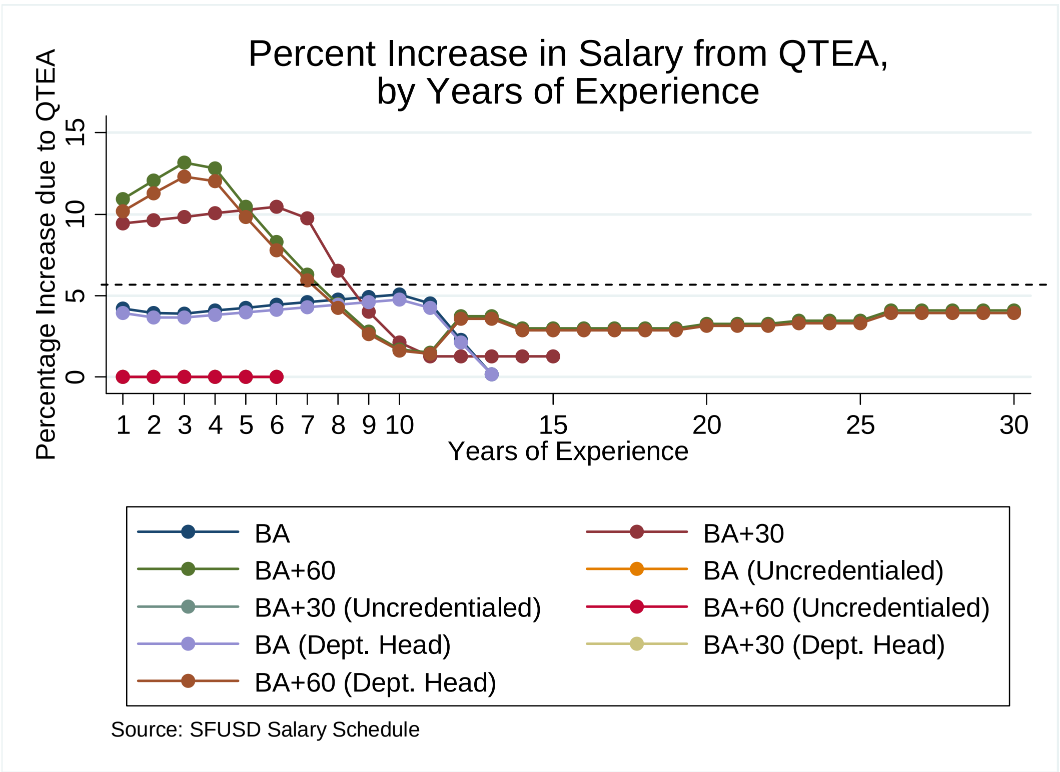


Figure 3.

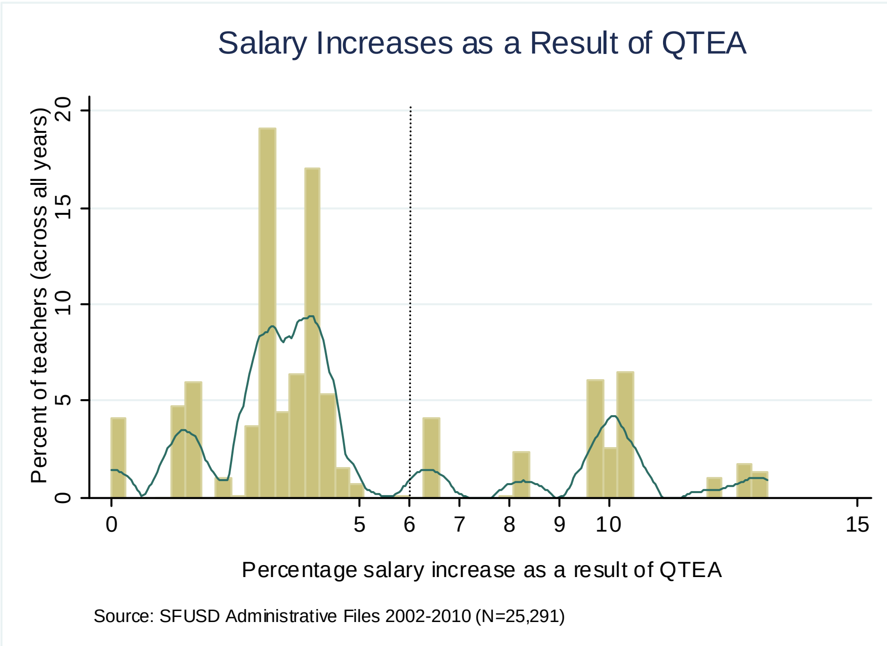


Figure 4.

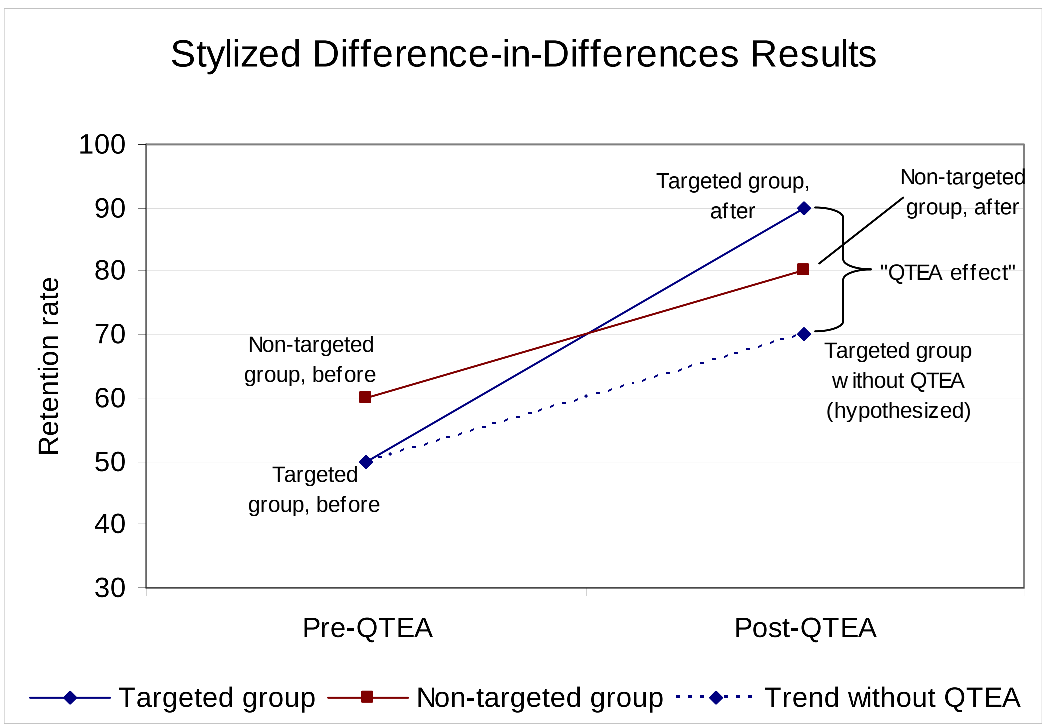


Figure 5.

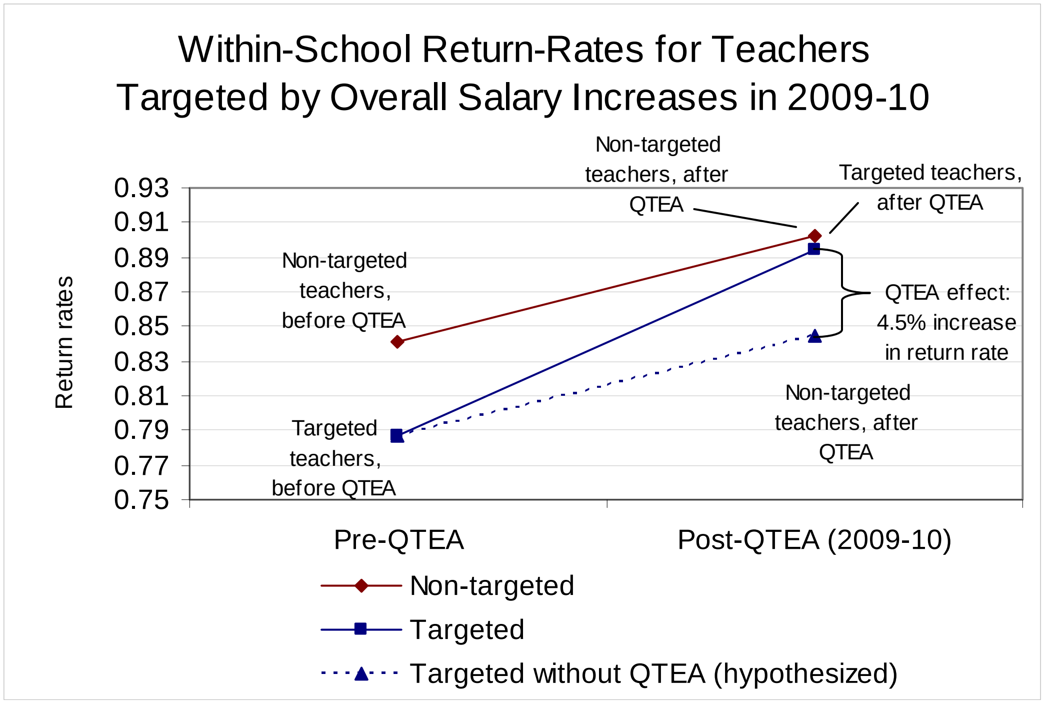


Figure 6.

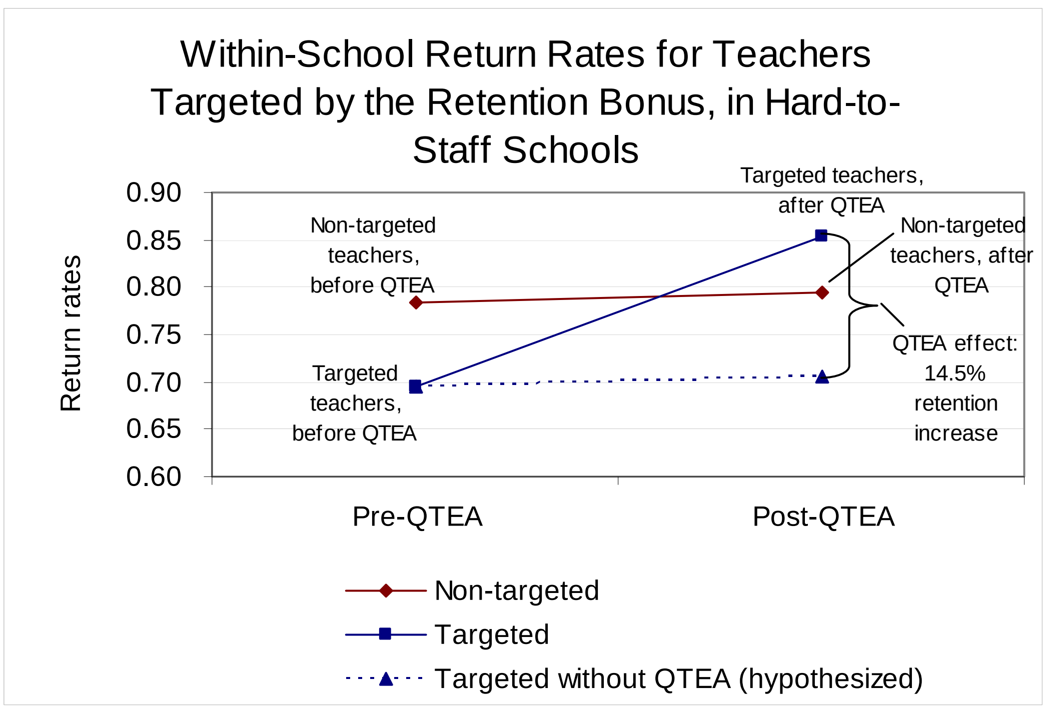


Figure 7. In-school return rates for teachers with high and low value-added scores, before and after QTEA

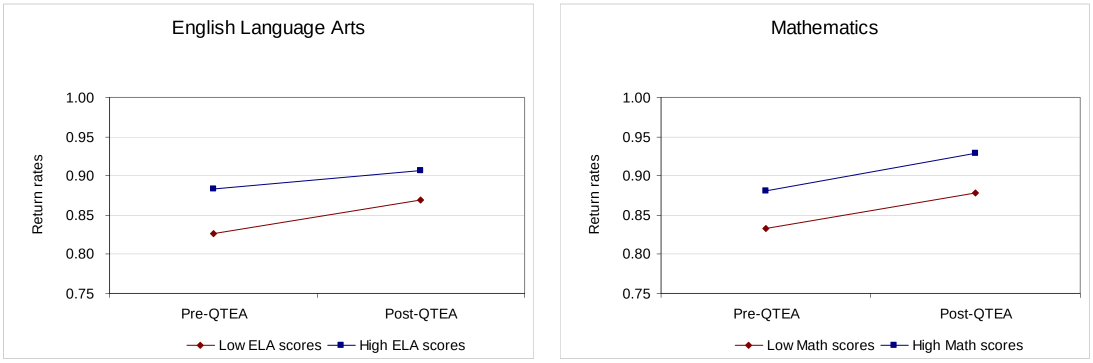


Figure 8.

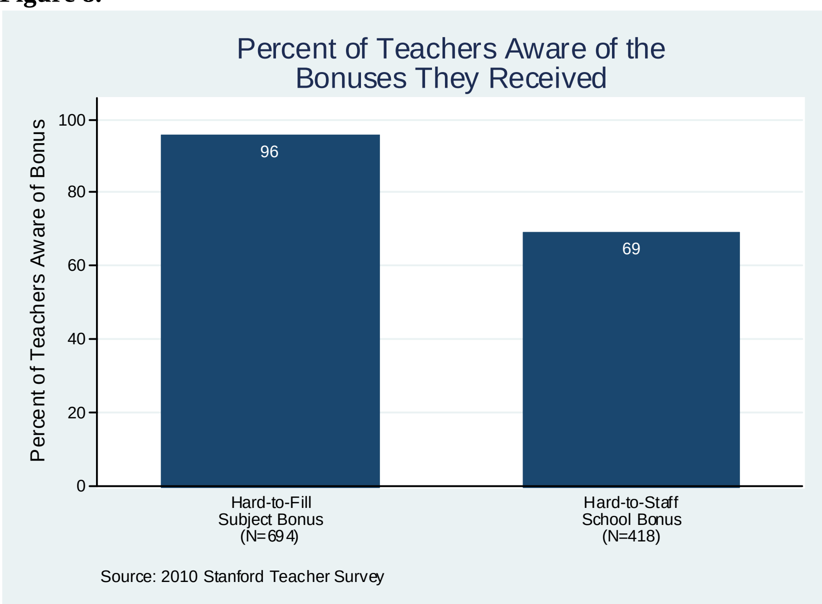


Figure 9.

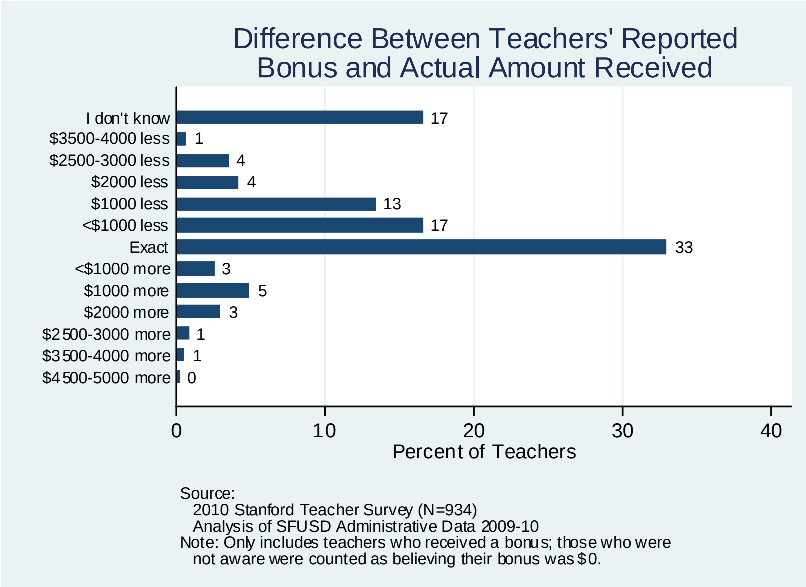
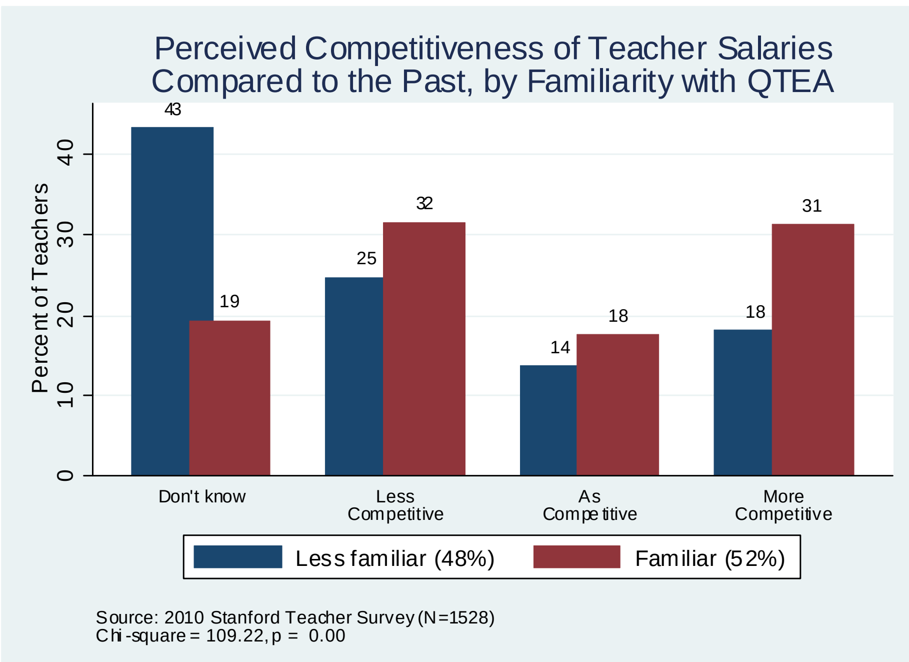


Figure 10.



Appendix A. Equation used to test varied definition of QTEA implementation period

$$P_{ij+1}^{h}=\frac{\exp(\beta_0^{h}+\beta_1^{h}TARG_{ij+1}+\beta_2^{h}2009_{j+1}+\beta_3^{h}2010_{j+1}+\beta_4^{h}2011_{j+1}+\beta_5^{h}TARG_{ij+1}*2009_{j+1}+\beta_6^{h}TARG_{ij+1}*2010_{j+1}+\beta_7^{h}TARG_{ij+1}*2011_{j+1})+\beta_8^{h}SIG}{\sum_{g=1}^{G}\exp(\beta_0^{g}+\beta_1^{g}TARG_{ij+1}+\beta_2^{g}2009+\beta_3^{g}2010+\beta_4^{g}2011_{j+1}+\beta_5^{g}TARG_{ij+1}*2009_{j+1}+\beta_6^{g}TARG_{ij+1}*2010_{j+1}+\beta_7^{g}TARG_{ij+1}*2011_{j+1})+\beta_8^{g}SIG}$$

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