The Effect of Alternative Compensation Programs on Teacher Retention and Student Achievement: The Case of Q Comp in Minnesota

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Abstract

The purpose of this study was to examine the effect of alternative teacher compensation programs (ACPs) on teacher retention rates and average student achievement in schools. ACPs base teacher pay mainly on some measure of their performance, such as student achievement, leadership, professional knowledge and skills, and instructional behavior. This study used the Minnesota Quality Compensation program (Q Comp) case to examine the effect of ACPs.

The relationships between ACPs and 3 types of school-level outcomes were explored: overall teacher retention rate, retention rate of teachers with three or more years of teaching experience, and rate of students who were at or above the proficiency level (student proficiency rate). In addition, it was also examined whether ACPs' effects on those three school-level outcomes differed by type of school, charter or traditional.

This study investigated teacher retention rates and student proficiency rates in Minnesota public schools over 8 years, 2003-2010. Because Q Comp began from the 2005-06 school year, the research period makes it possible to examine the effect of Q Comp implementation for up to 5 years, which was a long investigation relative to previous studies. Data on assignment of Minnesota public schools teachers developed by the Minnesota Department of Education and publicly posted on the Pioneer Press website were used to calculate teacher retention rate by school level. The school-level student proficiency rate for the third-grade mathematics and reading tests of the Minnesota Comprehensive Assessment (MCA) was used to measure school-level student achievement. To minimize selection bias problem, this study adopted a fixed effects

model to control for unobserved time-invariant variables across schools as well as to consider time-variant observable variables.

This study found a positive effect of Q Comp on overall teacher retention rate only in schools with 5 years of implementation. In addition this positive effect, charter schools with 5 years of Q Comp implementation faced a negative effect of Q Comp on overall teacher retention rate. A positive effect of Q Comp on retention rate of teachers with 3 or more years of teaching experience was also found only in schools with 5 years of implementation. Regarding the effect of Q Comp on student achievement, this study did not find any significant overall effect on schools. Charter schools with 3 years of Q Comp, however, enjoyed a positive and significant effect on the third-grade math proficiency rate.

The findings of this study imply that it takes ACPs some time to realize their effect. It took about 5 years of implementation in the case of Minnesota Q Comp for there to be an effect on teacher retention rate, which is a contribution of this study. Another contribution of this study is the finding that the effect of ACPs could differ by school type. The findings could lead to further discussion on whether the effect of ACPs could be sustainable and whether the positive effect on teacher retention rate would lead to improvement in student achievement, which remain considerations for future studies.

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CHAPTER I: INTRODUCTION

In this accountability era, there have been increasing concerns and various efforts to improve school performance by focusing on student achievement. Given the considerable size of teachers' contributions to student achievement, much of this effort on the part of policymakers have focused on teachers (Archibald, 2006; Goldhaber & Brewer, 1999). An increasingly popular strategy has been an attempt to align teacher compensation with teacher performance to motivate teachers to perform better (Odden & Kelley, 2002). This study proposes to examine the effect of an alternative teacher compensation program implemented in public schools in Minnesota.

Background of this Study

The relatively mediocre achievement of American students compared to those of other countries has been a serious concern for many US policymakers. According to results of the Organisation for Economic Co-operation and Development (OECD) Program for International Student Assessment (PISA; Fleischman, Hopstock, Pelczar, & Shelley, 2010), for example, 15-year-old American students showed an average score of 487 on the 2009 PISA mathematics literacy scale. This score was lower than the OECD average score of 496 for this cohort. In the science literacy scale of the 2009 PISA, the average score of American students, 502, was similar to the OECD average level, 501. These low scores were not a new trend. The average U.S. mathematics scores on the previous PISA tests were 483 in 2003 and 474 in 2006, and the 2009 PISA mathematics score of 487 showed no improvement over the course of six years. This ordinary or lower achievement level has been pointed out as problematic and characterized as a symptom of the decline in U.S. competency (e.g., National Commission on Excellence in Education, 1983). That problem definition leads us to a question about the factors that can influence the improvement of student achievement.

Student Achievement and Characteristics of Teachers

Studies on the factors related to student achievement have found that students' achievement varies by students' individual characteristics, family backgrounds, and school characteristics. For example, Goldhaber and Brewer (1999) disaggregated the variance in student achievement using a three-way nested-error model. They found that 8.52% of the variance in student achievement was related to the teacher level, 8.62% of the variance was related to the school level, 4.12% of the variance was related to the class level, and the other variance was due to the individual and family levels (Goldhaber & Brewer, 1999, p. 207). This finding suggests that about 21% of the variance in test scores among students were related to the differences in their schools, classes, and teachers. Also, about one-third of the school-related variance was associated with teachers (8.52% over 21%).

In another study that examined the effect of school resources on student achievement, Archibald (2006) also disaggregated the variance of student achievement into student level, class level, and school level by applying a hierarchical linear model (HLM). She reported that about 82% of the variations in reading scores were at the student level, 4% were at the class level, and 16% were at the school level. For math scores, about 74%, 8%, and 19% were at the student, class, and school level, respectively (Archibald, 2006, p. 33). The finding showed that about 20% of variance in reading scores and 27% in math scores were associated with school-related resources. Among the school-related variance, about one-fifth (4% over 20% in reading) to one-fourth (8% over 27% in math) of the school-related variance were associated with classes or teachers.

From the two studies, we found that at least 20% of the variance in student achievement was related to school characteristics. This degree of influence is smaller than the remaining factors from individual and family backgrounds, which accounts for about 80% of the variance. However, policymakers typically can exert greater control over school characteristics, including class and teacher characteristics, than individual and family attributes. Consequently, it is important to understand which characteristics of schools are related to student achievement.

As a school resource associated with student achievement, teachers are important. As seen in the two studies above, teacher-related variance accounted for one-fifth to one-third of the school characteristics associated with student achievement. Moreover, as Odden and Kelley (2002) argued, executing various efforts to improve schools, including rigorous curriculum standards (Alexander, 2003), class size(Finn & Achilles, 1999), or amount of financial expenditure (Odden & Picus, 2008), depends mainly on teachers. This argument also supports the importance of teachers as a school resource related to student achievement. The conclusion that teachers matter in improving student achievement leads to a question of how to improve teaching as it relates to student achievement.

Motivation, Professional Development, and Compensation

One way to improve teaching is to reform the teacher compensation policy (e.g., National Commission on Excellence in Education, 1983). This approach is from an assumption that the existing single–salary schedule would not motivate teachers to give their best performance (Lazear, 2003; Odden & Kelley, 2002).

In 1921, the single–salary schedule was first introduced in the U.S. in the Denver and Des Moines school systems (Sharpes, 1987). Under the single–salary schedule, teachers received different compensation according to their teaching experience and levels of academic preparation (Odden & Kelley, 2002). This system of compensation was considered to be fairer than the one it replaced because it compensated all teachers in the district on the same scale regardless of gender, race, grade level taught, or family status of the teacher (Educational Research Service, 1978, in Odden & Kelley, 2002).

In spite of its potential advantage in compensating teachers equitably, critics have pointed out that the single–salary schedule "[deprived] public school managers of authority to adjust an individual teacher's pay to reflect both performance and labor market realities" (Podgursky & Springer, 2007, p. 912). Opponents of the single–salary schedule argued that it could result in teachers not being motivated to improve the professional knowledge and skills associated with student achievement (Odden & Kelley, 2002). Critics called for alternative compensation programs (ACPs) in which teacher compensation is strategically connected with the development of professional knowledge and skills and student achievement. With alternative compensation aligning compensation with performance, teachers are expected to be more motivated and proactive to improve their capacities related to student achievement.

Alternative Compensation Programs

This study used the term ACPs differently from “performance-related pay” or “performance pay.” Some researchers used those terms to indicate compensation programs that reward teachers based only on their performance as measured by student achievement (e.g., Podgursky & Springer, 2007). The present study called those narrowly defined types of compensation “merit pay programs,” and they are reviewed in the next chapter as a sub-component of ACPs.

This study used the term ACPs to refer to those programs that typically compensate broad- based teacher performance, not just performance based on student achievement. That is, as used here, ACPs also compensate other performances of teachers, including career advancement, professional development, and the results of teacher evaluation (Azordegan, Byrnett, Campbell, Greenman, & Coulter, 2005; Brodsky, DeCesare, & Kramer-Wine, 2010). ACPs in this study encompass all of those elements, direct and indirect, associated with improving student achievement.

It is not difficult to find examples of ACPs. They include the Teacher Advancement Program of the National Institute for Excellence in Teaching, Professional Compensation System for Teachers of Denver in Colorado, and Minnesota Quality Compensation Program (Azordegan et al., 2005; Odden & Kelley, 2002). The U.S. federal government also increased their effort to support these alternatives through the Teacher Incentive Fund (TIF) Program. For example, the appropriated funding of the TIF program started at $99 million in 2006 and increased to $400 million in 2010, a nominal increase of just over 300 percent in under 5 years (U.S. Department of Education, 2010).

Purpose and Organization of this Study

The purpose of this study is to examine the effect of an alternative teacher compensation program. Although there has been increased interest in adopting and implementing ACPs, there have been few studies examining their effect. According to Podgursky and Springer's (2007) review, there have been few rigorous experimental or quasi-experimental studies on the effect on student achievement of ACPs implemented within U.S. schools. While some institutes have recently published empirical studies, few studies were found in peer-reviewed journals.

Chapter II begins with a review of the literature on the relationship between student achievement, teachers' teaching experience, and teachers' graduate degrees. Teaching experience and education were examined closely because these factors drive compensation for the existing single–salary schedule. The weak associations of these factors with student achievement have been at the center of the critique against the single –salary schedule (Goldhaber, 2008; Odden & Kelley, 2002; Podgursky & Springer, 2007). I also reviewed the scholarship on the underlying theory and practice associated with alternate compensation programs. Based on this review, Chapter II explores the theory of logic underlying ACPs and presents my assessment of studies examining the effect of ACPs. The chapter closes with a discussion of the gaps in the literature and key research questions that emerge.

Chapter III outlines the research design and data sources used in this study. This chapter briefly introduced the Minnesota Quality Compensation Program (Q Comp), an ACP case that this study selected as an object of analysis. This is a good program to explore the impact of ACPs because its initial implementation in 2005 provides a long enough history where its effects may be analyzed. This is an advantage over other studies where the long-term impact of ACPs was not fully explored because of their relative novelty. The chapter continues with a description of the conceptual frameworks employed to analyze teacher retention rate and student achievement, which the theory of logic indicates would improve with implementation of ACPs. Chapter III also includes a description of the variables and equations used in analyzing the impact of ACPs.

Chapters IV and V provide the results of the analyses and discuss the estimates of the coefficients derived from the equations described in Chapter III. Chapter IV presents the results of the teacher retention rate model, and the results of the analyses of the student achievement model are presented in Chapter V.

Finally, Chapter VI concludes with a summation of the results and discusses the implications of the findings. It also indicates the limitations of this study and offers guidelines for future research.

CHAPTER II: LITERATURE REVIEW

Teaching Experience, Graduate Degrees, and Student Achievement

Alternative compensation programs for teachers have developed from an assumption that the existing single–salary schedule has limitations in motivating teachers to improve their performances (Odden & Kelley, 2002). Single–salary schedules mainly depend on years of teaching experience and graduate degrees to increase the amount of compensation given to teachers. Critics, however, have been concerned that those characteristics are not necessarily associated with student achievement, an important indication of the performance of teachers (e.g., Hanushek, 1989). If their concerns are valid, under the single–salary schedule, teachers may be compensated regardless of how well their students perform. As a result, opponents of a single–salary schedule for teachers argue that the existing compensation programs fail to motivate teachers to focus on student achievement. This chapter begins with a review of the studies examining the role of teacher attributes on student achievement.

Teaching Experience

As Lortie (1975, p. 60) metaphorically expressed, teachers "sink or swim" in the classroom and develop much of their professional abilities through their experiences. Many studies using education production functions have supported the notion that teachers with more teaching experience show greater effects on student achievement. For example, Ferguson (1991) divided teaching experience in school districts into three categories: the percentage of teachers with fewer than five years of experience, those with five to nine years of experience and those with more than nine years of experience. He compared the relationship among the various years of teaching experience with the district's average reading scores. In the analysis, he found that student reading scores increased significantly when the percentage of teachers with five to nine years of experience replaced the percentage of teachers with fewer than five years of experience. Replacing teachers with fewer than five years of experience with teachers having more than nine years of experience was also related to an increase in the standardized achievement scores. From the result, we can see the positive effect of teaching experience on student achievement.

An important question regarding the relationship between experience and student performance is whether the association is linear. Considering Ferguson's (1991) study, he found that "in the primary grades, … once teachers have five years of experience, additional years do not add to their effectiveness" (Ferguson, 1991, p. 476). For example, in the third grade reading scores, the difference in teacher quality between teachers with zero to five years of experience and teachers with five to nine years of experience was 0.022 ($t = 3.70$, Ferguson, 1991, p. 493). On the other hand, the difference between teachers with zero to five years of experience and teachers with more than nine years of experience is 0.016 ($t = 4.51$, Ferguson, 1991, p. 493). It was smaller than the previous group difference, which implied that the effect of teachers with five to nine years of experience would not be bigger than the effect of teachers with more than nine years of experience.

Whereas Ferguson's (1991) study showed the decreasing coefficient of teaching experience, he said little about the differences within the first five years of experience. Rivkin, Hanushek, and Kain (2005) looked specifically at the association between the first five years of teaching and student achievement. They used math and reading test scores of third to seventh graders in Texas public schools from 1993 to 98. They included four categorical variables to measure teaching experience: teachers with less than one year of experience, teachers with one year of experience, teachers with two years of experience, and teachers with three or four years of experience. The omitted category was for teachers with five or more years of teaching experience. By using this strategy, the authors were able to compare more experienced teachers with less experienced teachers. In the study, Rivkin et al. (2005) found "important gains in teaching quality in the first year of experience … [but] little evidence that improvements continue after the first three years" (Rivkin et al., 2005, p. 449). This finding indicated a more limited effect of teaching experience than Ferguson's (1991) study.

Clotfelter, Ladd, and Vigdor (2006) examined the effect of teaching experience for elementary teachers divided into six categories of years of teaching experience: 1 to 2, 3 to 5, 6 to 12, 13 to 20, 21 to 27, and more than 27 years. In this study, the effect of each category was compared to the effect of zero-experienced teachers. They used fifth graders' math and reading scores in North Carolina public schools in the 2000–2001 school year as their dependent variable. They found that all experienced teacher groups were more effective than the new teacher group in student achievement gain and the maximum effectiveness was shown in the more than 27 years of experience group. They specified, however, that "roughly half of this return occurs for the first one or two years of teaching experience" (Clotfelter et al., 2006, p. 807). This is similar to Rivkin et al.'s (2005) study in terms of the large growth in the first few years of experience and smaller gains later.

Clotfelter, Ladd, and Vigdor (2010) also examined the effect of teaching experience of high school teachers. They looked at the exam scores of 10th graders in North Carolina public schools from the 1999–2000 to 2002–2003 school years. They included the same teaching experience categories as Clotfelter et al. (2006) and reached a similar conclusion. They reported that all experienced teacher groups were more effective than new teachers, and the maximum effect appeared in teachers with 21 to 27 years of experience (β=0.0629, s.e.=0.005 in Clotfelter et al., 2010, p. 665). Moreover, similar to the previous studies, the marginal improvement in student achievement attributed to teachers mostly appeared within the first two years of teaching. The effect of teachers with three to five years of experience compared to teachers with no experience was 0.0608 (β=0.0608, s.e.=0.005 in Clotfelter et al., 2010, p. 665). The effect, 0.0608, was not significantly different from the effect of teachers with 21–27 years of experience, the maximum effect (Clotfelter et al., 2010, p. 666).

As shown, Rivkin et al.'s (2005) study argued that teachers with fewer than three years of experience have been observed to be less effective in improving student test scores than teachers with three or more years of experience. And Clotfelter et al.'s (2006, 2010) studies did not have results largely different from Rivkin and her colleagues. Findings, however, were mixed on the issue of whether or not teachers would consistently increase their effectiveness with more than three years of teaching experience.

Graduate Degrees

We can expect that graduate degree courses will improve teachers' knowledge, skills, and disposition, and thereby teacher quality. However, empirical studies are less supportive of the assumption that teachers with graduate degrees influence student achievement more than teachers without. For example, Ferguson (1991) found that the percentage of teachers with graduate degrees in school districts was not significantly associated with students' reading test scores. Alexander (1998) also found that there was no significant association between the graduate degrees that teachers held and student achievement.

More recent studies show consistent results with Ferguson (1991) and Alexander (1998). Rivkin et al.'s (2005) study with fourth to seventh graders' math and reading data reported that the proportion of teachers with graduate degrees was not related to gains in students' test scores (β= -0.018, *s.e.*=0.017). Clotfelter et al.'s (2010) study of high school data also reported a statistically insignificant effect concerning teachers' graduate degrees (β=0.0024, *s.e.*=0.002). Moreover, Clotfelter et al.'s (2006) study of elementary school data found that teachers with graduate degrees were significantly less effective than those without graduate degrees (Clotfelter et al., 2006, p. 798).

Given the insignificant or negative effect of graduate degrees, it is difficult to say that graduate degrees can reflect the quality of teachers despite theoretical assumptions. The results could be caused by some methodological issues. First of all, teachers with graduate degrees are likely to have more teaching experience, as Clotfelter et al. (2006) indicated for their dataset. This means that there is the possibility of multicollinearity when graduate degrees are included in regression models with teaching experience. A multicollinearity problem could potentially increase the standard error of the coefficients in the regression models. As a result, the tendency of rejecting the hypothesis of the *t*-test for the βs would decrease (Gujarati & Sangeetha, 2008). It could explain why some empirical studies found no significant effect of graduate degrees. However, it is still hard to explain their negative effect.

Second, and more important, the studies listed above do not identify the fields of study that the graduate degrees represent. For example, when teachers earn a graduate degree in educational administration, it may be less reasonable to expect these teachers to increase the math scores of their students than to expect teachers with graduate degrees in math education to do so.

Third, the insignificant results may be attributed to the efforts of teachers' colleges and states to improve initial licensure programs and intensify state licensure requirements. The efforts could improve the quality of initial licensed teachers (Darling-Hammond, 2000). Those efforts could reduce the difference in quality between teachers with and without graduate degrees.

We need to be cautious in drawing conclusions on the effects of graduate degrees. Thus, we cannot conclude, based on the existing research, that graduate degrees in and of themselves are significantly associated with higher student achievement.

Development of Alternative Teacher Compensation

Even though more research would be helpful, the present status of the scholarship indicates that teaching experiences and graduate degrees seem to be weakly associated with student achievement. Consequently, teachers with characteristics associated with higher student achievement would not necessarily be rewarded under compensation programs based on those characteristics. This leads to concerns that there would be little motivation for teachers to improve their ability as related to increases in student achievement under current single-salary compensation programs, which are based on years of experience and education (Lazear, 2003; Odden & Kelley, 2002; Podgursky & Springer, 2007). Alternative policy ideas to address these concerns, therefore, are focusing on “paying for outcomes” to align compensation with performance.

Merit Pay Program

Merit pay is “a generic term for any device that adjusts salaries or provides compensation to reward higher levels of performance” (Ellis, 1984, p. 2). The level of performance is usually determined by a supervisor or by peer review (Odden & Kelley, 2002). The merit pay program is devised to motivate teachers to perform better largely based on expectancy theory (Hasnain & Pierskalla Henryk, 2012; Odden & Kelley, 2002).

The expectancy theory proposed by Vroom (1964) and Porter and Lawler (1968) hypothesizes that the level of force that an employee exerts to get a performance would be a function of expectancy and valence for the performance (Heneman & Schwab, 1972). Here, the expectancy is the perceived probability that a certain level of effort will result in the achievement of each performance level, and the valence refers to “the strength of the [employee]’s desire for an outcome” (Lewin, 1938 in Galbraith & Cummings, 1967, p. 239). The valence for the performance (the first-level outcome) is determined by all events which are affected by the performance (the second-level outcome) and the instrumentality, “the perception of the relationship between the first and the second level outcome” (Galbraith & Cummings, 1967, p. 239).

This implies that by guaranteeing merit pay for an increased level of performance, school leaders can affect the valence for the increased performance of teachers and can increase the teachers’ effort to get that increased performance. The premise is that teachers should believe that they have the ability to get the increased level of performance, and their increased efforts will lead to the level of performance sought.

Besides the motivation effect of the merit pay program, Lazear (2003) argued that a teacher sorting effect could be expected from merit pay programs. Merit pay programs based on teacher performance will pay more to teachers evaluated as showing high performance and will pay less to teachers who are lowly evaluated. Assuming that teachers with higher compensation are more likely to stay in their schools (Clotfelter, Ladd, & Vigdor, 2011; Hanushek, Kain, & Rivkin, 2004), merit pay program will attract and retain more highly rated teachers and fewer lowly rated teachers. As a result, Lazear (2003) argued that this sorting process will result in improving teaching in the schools.

In spite of theoretical expectations on motivation or sorting, there have been critiques against introducing it in the teaching profession. An important critique is that external motivation would be effective for simple tasks but not effective for complex and ambiguous tasks (Austin, 1996 as cited in Osterloh & Frey, 2002). Considering that teaching has been known to incorporate complex and ambiguous tasks (Weick, 1976), balancing external and internal motivations would be important for effective motivation, as Osterloh and Frey (2002) argued.

In addition, investigating successful and failed merit pay programs in schools, Murnane and Cohen (1986, p. 7) found that the school leaders adapting the merit pay programs faced difficulties in answering "why does worker X get merit pay and I don't?" and "what can I do to get merit pay?" They argued that the difficulties resulted from the characteristic of the teaching profession, where effective teaching cannot be characterized as the consistent use of particular, well-defined techniques. On the other hand, they found some successful merit pay programs which worked by modifying key characteristics of established merit pay programs. Murnane and Cohen (1986, pp. 12–15) summarized the modifying characteristics of the revised programs with four themes: They compensated "extra pay for extra work" rather than for better performance in classroom instruction; They "[made] everyone feel special" rather than gave differential rewards to make high-performing teachers feel special; They "[made] merit pay inconspicuous" rather than giving information on who get rewards to stimulate better performance; and they "[legitimated] through participation" of teacher in designing the program. And as the authors mentioned, those themes "changed one or more crucial aspects of the merit pay ideas… [thus] economists would not view them as examples of performance-based compensation" (Murnane & Cohen, 1986, p. 12).

Team-Based Merit Pay

Another critique against merit pay programs is that those programs would cause competition among teachers, which hurts teamwork in schools (Podgursky & Springer, 2007). To address this negative effect, some programs were designed to offer merit pay based on team, not individual, performance. Odden and Kelley's (2002) knowledge- and skills-based pay program and North Carolina's ABCs of Public Education (Vigdor, 2008) are examples of programs that offer rewards based on teams rather than individuals. In an empirical study of Israeli schools, Lavy (2002) found that school-wide incentive programs significantly improved student achievement.

However, the team merit pay program has a possibility of a “free rider” problem in which some individuals enjoy the outputs produced by the group without increasing their own efforts (Lazear, 2003). If free riders were compensated equally with the other teachers, it will result in decreases in the other teachers’ motivation and, ultimately, overall group performance. Additionally, Lazear (2003) argued that the teacher sorting effect would not be expected in the team-based merit pay because free riders or lowly rated teachers would receive merit pay based on the team performance.

Career Ladder System

The career ladder system appoints better performing teachers in leadership positions and rewards them with more pay for their better performance, not only for improved student test scores but also for their leadership contributions (Odden & Kelley, 2002). An important attribute of the career ladder system is to offer professionalism-focused benefits. Compared to traditional merit pay programs that focus on monetary benefits, career ladders seem to address more directly teachers’ resentment, low morale, and anti-cooperative behavior (Dee & Keys, 2004).

The career ladder program is not free from a question of whether the program could reward better teachers. Dee and Keys (2004) addressed this question in their study of the Tennessee’ Career Ladder Evaluation System in the mid-1980s. They found some positive evidence that students of teachers in the upper rung showed better achievement in reading than students of teachers in the lower rung. However, they also found that students of teachers in the lower rung showed better achievement in math than students of teachers in the upper rung. Because of mixed results across subjects, it is hard to say that the career ladder program would identify better teachers to place in the upper rung.

Knowledge- and Skills-Based Pay Program

The knowledge- and skills-based pay programs compensate teachers for the development of four types of professional knowledge and skill: knowledge and skills in (1) classroom instruction, (2) educational functional tasks, (3) school management and leadership, and (4) professional activities (Odden & Kelley, 2002). Odden and Kelley (2002) criticized the existing single–salary schedule because it increases compensation mostly based on indirect indicators of knowledge and skills such as years of teaching experience, education units, and university degrees. Therefore, they tried to replace those indirect indicators with more direct measures of teacher knowledge and skills. They listed various teaching standards developed by various institutes, including the PRAXIS III, the Interstate Teacher Assessment and Support Consortium (INTASC), the National Board for Professional Teaching Standards, and Danielson’s Framework for Teaching. Adapting those standards and reflecting local standards of schools and districts, they argued schools could build customized developmental stages of teachers’ knowledge and skills. They also believe teachers can increase the number of roles they can perform in schools with the acquisition of additional expertise.

Let’s recall the two questions Murnane and Cohen (1986) issued for the merit pay program – “why does worker X get merit pay and I don’t?” and “what can I do to get merit pay?”. The knowledge- and skills-based pay programs seem to tell teachers what they need to do to achieve high performance by offering developmental stages and standards of teachers’ knowledge and skills. Therefore, if the knowledge- and skills-based pay program could clearly present the standards of each developmental stage and how strongly the goals should be associated with students’ achievement, it would successfully address Murnane and Cohen’s (1986) questions and achieve higher teacher motivation, higher teacher performance, and higher student achievement.

Alternative Compensation Programs

Even though this study reviewed some alternative ideas on teacher compensation programs, practical alternative programs tend to be designed as a bundle of those alternatives reviewed above. For example, the Minnesota Quality Compensation (Q Comp) program, which is the focus of the analysis of this study, includes facets of career ladder, knowledge- and skills-based pay, and merit pay focusing on student achievement (Minnesota Office of the Legislative Auditor, 2009); the Teacher Advancement Program of the National Institute for Excellence in Teaching (National Institute for Excellence in Teaching, 2012) includes multiple components as well.

Because of their comprehensiveness, the alternative compensation programs (ACPs) do not only focus on teacher performance based on student achievement as do some merit pay programs (e.g., Lazear, 2003). They also compensate other performances of teachers that reflect advancement in those knowledge and skills of teachers which are associated with improvement of school level student achievement as well as performances directly measured by student achievement.

It is an important characteristic of ACPs to emphasize not only student achievement but also the development of knowledge and skills of teachers (e.g., Timar & Roza, 2010). This is because focusing on professional development can reduce some of the concerns regarding merit pay programs. One important critique is that extrinsic motivation, upon which merit pay programs are based, can “crowd out” intrinsic motivation (Osterloh & Frey, 2002). According to Osterloh & Frey’s (2002) explanation, external rewards have two aspects: controlling and informing. The controlling aspect strengthens teachers’ perception of external control while the informing aspect influences perceived competence. If the informing aspect is prominent, the external rewards could raise intrinsic motivation. On the other hand, in cases where the controlling aspect is prominent, teachers no longer feel responsible for goals and values but rather attribute responsibility to those who reward their performance. As a result, intrinsic motivation is crowded out. Because intrinsic motivation is related not only to the performance being rewarded (e.g., academic test scores) but also to any other of a variety of school goals (e.g., students’ safety), crowding out intrinsic motivation could lead to a reduction in other important aspects of teacher performance (Osterloh & Frey, 2002). Moreover, a decrease in intrinsic motivation could be related to a decrease in job satisfaction and an increase in teachers’ decision to leave (e.g., Shapira-Lishchinsky, 2012). Considering that increases in teachers leaving could negatively influence student achievement (Guin, 2004), a decrease in intrinsic motivation could offset the expected positive effects of merit pay programs on extrinsic motivation and student achievement. Therefore, teacher compensation programs need to be designed to motivate teachers intrinsically as well as extrinsically.

Contrary to simple merit pay programs, Odden and Kelley (2002) argued that more comprehensive ACPs could strengthen intrinsic motivation of teachers by offering help with professional development, i.e., strengthening the informing aspect of incentives. For example, many ACPs create positions for mentors and teacher leaders to help with other teachers' professional development. Teacher evaluations or advanced certifications, such as the National Board Certification, give teachers standards for advanced knowledge and skills and facilitate them achieving those standards. Through professional development, teachers can have control over the quality of their work and create a sense of professional efficacy, which is associated with intrinsic motivation. Therefore, Odden and Kelley (2002) argued that ACPs can help teachers to be motivated not only extrinsically, but also intrinsically, to perform their work better.

The characteristics of ACPs to motivate teachers intrinsically as well as extrinsically could be meaningful in practice. According to interviews with teachers, teachers believe that monetary incentives could positively affect professional development or instructional practice, which could improve indirectly student achievement (Wahlstrom, Sheldon, & Peterson, 2006). On the other hand, teachers were reported to have less trust in the direct relationship between monetary incentives and student achievement. Based on these findings, monetary incentives would be more likely to motivate teachers to improve their instructional practice than they would motivate teachers to increase students' test scores directly. Considering the inducement characteristics of ACPs, focusing on professional development as well as student achievement in the development of ACPs would be important for effective implementation.

Expected Effect of Alternative Compensation Programs

As a compensation program encompassing merit pay and knowledge- and skills-based pay, ACPs are designed to motivate teachers to develop their knowledge and skills to improve student achievement. In addition, teacher retention studies conclude that schools' support for teachers to develop their knowledge and skills can improve the schools' teacher retention rates. Therefore, it is assumed that ACPs will change the behaviors of individual teachers and students, which in turn will affect changes in school level indicators of teacher retention rates and student achievement.

ACPs and Teacher Retention

Teacher retention rate refers here to the percentage of teachers who come back to a school in an academic year among the teachers who worked in that school in the previous academic year. This study, moreover, restricted the range of teachers to those teachers who teach core academic subjects as defined by the Minnesota Department of Education.

Teacher retention rate is an important school characteristic about which school policymakers are concerned. This is because schools with low teacher retention rates experience difficulty in planning and implementing a coherent curriculum and sustaining positive working relationships among teachers (Guin, 2004). The negative impacts of low teacher retention rates can hurt teachers' teamwork and schools' outcomes (Guin, 2004).

Losing teachers also generates high costs, including the cost of separation, replacement staffing, and training new teachers (Watlington, Shockley, Guglielmino, & Felsher, 2010). According to Watlington et al.'s (2010) study, the costs associated with replacing a teacher were calculated to be $4,631 and $12,652 per teacher in two Southeast Florida school districts in the 2004–05 academic year. The variation in the cost to replace teachers was mainly from the differences in the districts' induction or professional development programs. The costs incurred in replacing teachers can create a burden for the school financially.

Considering the organizational and financial importance of teacher retention rates of schools, it is important for school policymakers and school administrators to understand factors associated with teacher retention rates and to manage them. Previous studies on teacher retention supported the possibility of ACPs improving the teacher retention rates of schools. ACPs could support teachers in developing their knowledge and skills associated with student achievement (Odden & Kelley, 2002). According to the teacher retention literature, opportunities and administrative support for professional development are important factors associated with teacher retention (Guarino, Santibañez, & Daley, 2006). Because teachers want to develop their knowledge and skills in the teaching profession, they prefer schools with working conditions supportive of professional development. This preference affects teachers' decisions to choose the schools where they work (Liu, Rosenstein, Swan, & Khalil, 2008). Therefore, schools with supportive working conditions for professional development could reduce the number of teachers who move to other schools. As a result, they are more likely to have higher teacher retention rates.

Moreover, advanced professional knowledge and skills because of professional development efforts are associated with reducing the rate at which teachers leave the teaching profession. According to Chapman (1983), advanced professional knowledge and skills reflect advancement in professional integration into teaching. Advanced teachers' integration into teaching increases career satisfaction and positively affects teachers' decisions to stay in the teaching profession. Therefore, schools that develop teachers' professional knowledge and skills can reduce the number of teachers who leave the teaching profession. As a result, they are more likely to have higher teacher retention rates. A recent empirical study supported the argument that schools that are more supportive of professional development are less likely to lose teachers not only to other schools, but also to other professions (Boyd et al., 2011).

In summary, teacher retention studies conclude that schools' support for teachers to develop their knowledge and skills can improve the schools' teacher retention rates. Based on this conclusion, this study hypothesized that well designed ACPs that support professional development of teachers can improve the teacher retention rates of schools.

ACPs and Retention of Experienced Teachers

This study was also interested in teacher retention rates of teachers with three or more years of teaching experience (hereafter, experienced teachers). This matter stemmed from concerns that schools must put more effort to retain teachers with characteristics that are identified as being associated with higher student achievement (e.g., Boyd, Grossman, Lankford, Loeb, & Wyckoff, 2009; Goldhaber, Gross, & Player, 2007). Discussion of what characteristics of teachers matter in terms of student achievement is not conclusive (Goldhaber, 2008; Strong, 2011). However, at the heart of the discussion, there has been consistent support that teachers with three or more years of teaching experience would be more effective at improving student achievement than those with zero, one, or two years of teaching experience (e.g., Clotfelter et al., 2006; Rivkin et al., 2005). Therefore, this study examined the association between ACPs and retention rates of experienced teachers.[1]

Compared to the single–salary schedule, ACPs would not increase teacher salary automatically or solely for increases in years of teaching experience. That is, salary increases would be linked to improvements in student performance as well as those attributes that are traditionally associated with this improvement. Thus, using ACPs, a teacher could be compensated for improved student performance, additional years of teaching experience, as well as service, professional development, and the knowledge and skills related with high performance. If the ACPs are designed to be supportive of teachers with many years of teaching experience, their presence would improve the retention rates of experienced teachers for those schools. It would be a meaningful research topic to examine whether ACPs' emphasis on the improvement of school performance effectively results in the retention of an important resource for schools, experienced teachers.

ACPs and Student Achievement

Student achievement measured by standardized test scores is an important output

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[1] Besides experience, teachers identified as Highly Qualified (HQ) as mandated by the No Child Left Behind Act (HQ teachers) may also be considered as teachers with important characteristics. While meaningful in theory, analyzing the relation between ACPs and retention rates of HQ teachers, however, may be meaningless in reality. That is, because of legal requirements, most teachers who teach core academic subjects are HQ teachers. For example, Minnesota reported that 97.65% of all core academic classes in Minnesota were taught by "highly qualified" teachers in the 2005–06 school year (Minnesota Department of Education, 2006a). As a result, the retention rates of HQ teachers are not very different from the retention rates of all teachers who teach core academic subjects. As stated previously, this study restricts the teacher retention analysis to those teachers of core academic subjects. Therefore, this study does not analyze the retention rates of HQ teachers separately.

of schools, so studies on policy effect have often been interested in it (e.g., Alexander, 2002). Moreover, there has been increased interest in student achievement as an indicator of school accountability. The No Child Left Behind Act, requiring all students to achieve proficiencies measured by statewide standardized tests in reading, math, and science by 2014, reflects this increased interest. Student achievement would be an important indicator that schools in the No Child Left Behind era should manage.

ACPs intend to improve student achievement in schools (Odden & Kelley, 2002). By guaranteeing higher compensation for improved student achievement, ACPs are assumed to motivate teachers to put more effort into improving student achievement. Adding to the motivation, ACPs support teachers in developing their knowledge and skills, and this can also lead to improved student achievement. As a result, student achievement in schools implementing ACPs will be expected to improve.

ACPs and Charter Schools

The last and distinctive concern of this study was about whether the effects of ACPs are different for different school types, focusing on charter schools compared to traditional public schools. Charter schools are public schools operated with more autonomy than traditional public schools in exchange for more accountability for the educational outcomes that they declare in their own charters (Hubbard & Kulkarni, 2009). With increasing concern about parents' rights for education and school accountability, charter schools are expected to provide innovation, competition, and academic improvement (Hubbard & Kulkarni, 2009). After the opening of the first charter school in St. Paul, Minnesota in 1992, there were 5,274 charter schools (Keaton, 2012, p. 7) serving 1,787,091 students (about 3.6% of the total of 49,177,617 students) in the United States in the 2010–11 academic year (Keaton, 2012, p. 9).

Previous studies on charter schools have compared them to traditional public schools (TPS). Yeh (2007) averaged the charter schools' effect sizes from three large-scale studies with panel data (Bifulco & Ladd, 2006; Hanushek, Kain, Rivkin, & Branch, 2005; Sass, 2006) that used rigorous statistical methods, considering student fixed effects to control for observable and unobservable characteristics that could cause selection bias. Yeh found negative average effects (-0.088 *SD* in reading and -0.116 *SD* in math).[2]

One reason for the negative effect of charter schools could be the staffing problems in charter schools. Charter schools are facing lower teacher retention rates than TPS, and typically have a smaller percentage of experienced teachers, a valuable teacher group in which this study is interested (Carruthers, 2012; Cowen & Winters, 2012; Stuit & Smith, 2012). These difficulties in staffing are often associated with low student achievement in charter schools (Carruthers, 2012; Stuit & Smith, 2012).

The staffing problems in charter schools seem to be associated with low salary and difficult working conditions. For example, according to the analysis of Stuit and Smith (2012) on self-reported reasons of teachers' leaving, teachers who left charter schools were more likely to indicate salary and working conditions, including

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[2] This unexpected negative effect could be related with time. As Yeh (2007) summarized, when charter schools only operating for five or more years were considered in the three reviewed studies, the average effect size for charter schools turned out to be positive (0.009 *SD* in reading and 0.001 *SD* in math). This result shows a possibility that charter schools' effect on student achievement would be improved as they mature with time. However, as Carruthers (2012) pointed out, there are many variations in charter schools' effects on student achievement, and more studies are needed to examine which school factors would be improved during the maturation to increase student achievement. This study focuses on the staffing problems of charter schools rather than time as an important factor associated with low student achievement of charter schools, as stated in the next paragraph.

administrative support, as reasons for leaving their schools than teachers who left TPS.

In summary, charter schools generally have worse working conditions and lower salaries than TPS, which could result in lower retention rates and lower student achievement. Therefore, if charter schools participated in ACPs to improve their working conditions and salary, they could improve teacher retention rates and student achievement.

More importantly, the effect sizes of ACPs in charter schools could be larger than those in TPS. According to the assumption of *diminishing marginal utility* in Economics, “an extra dollar of [input] provides a poor [school] with more additional utility than an extra dollar would provide to a rich [school]” (Mankiw, 2009, p. 442). If the diminishing marginal utility assumption was applied to the utility from additional input on teacher salary and working conditions, charter schools could get more utility than TPS from the same amount of input on teacher salary and working conditions. That is, if the same amount of extra input is provided to each type of school, marginal utility in charter schools could be bigger than in TPS because of the lower base level in the former. Thus, incentive-based programs could lead to higher improvement in teacher retention rates and student achievement in charter school environments.

Empirical Studies on the Effect of Alternative Teacher Compensation Programs

There is little evidence on the effect of ACPs on teachers or students. For example, Springer et al. (2009) analyzed the case of the Governor’s Educator Excellence Grant (GEEG) Program of Texas, which is a form of ACP. They found that the GEEG program was significantly related to the higher retention rate of all teachers only in the first implementing year but not in the second and third years. Therefore, it is difficult to say that the ACPs would increase the overall teacher retention rates. In the GEEG program, overall, teachers were not satisfied with the changing professional development support enough to change their retention-related decision making.

However, Springer and his colleagues showed evidence that the amount of incentives that individual teachers received affected the probability of the teachers leaving. In the study, teachers who received a large amount of incentive pay (e.g., more than $1,150 in the first year) showed a significantly reduced probability to leave their schools than the probability they would have showed when they were without the ACP program. In contrast, teachers who received a small amount of incentive pay (e.g., less than $650 in the first year) had a significantly increased probability to leave their schools. Based on this result, the GEEG seemed to affect the retention rate of a certain group of teachers who received a large amount of incentive pay.

The group of teachers receiving a large amount of incentive pay was assumed to meet high-performance criteria required by the ACPs. In this sense, as Lazear (2003) argued, the GEEG would function as a mechanism of teacher sorting. It, however, did not result in the improvement in student achievement at least within the three years examined. Even though Springer and his colleagues argued that the teacher sorting effect would result in the improvement of student achievement in the long term, they have not yet tested that assumption.

Springer et al. (2009) also found consistent results in another ACP program implemented in Texas, called the Texas Educator Excellence Grant (TEEG) Program. The TEEG program ran for three years starting in the 2006–07 school year. They found that the TEEG program was not significantly related to improvements in the teacher retention rate. However, they also found that teachers with a large amount of incentive pay showed reduced probability of leaving their schools, while teachers with a small amount of the pay expressed increased probability of leaving, as in the GEEG study. In the relationship between the TEEG and student achievement, the authors did not find any evidence of a significant relationship.

The third study reviewed is that of Glazerman and Seifullah (2010), who analyzed the effect of another ACP program, called the Teacher Advancement Program (TAP) in Chicago. They found that the retention rates of schools participating in the TAP program were not significantly different from those of non-participant schools, which is consistent with the two studies above. They also compared the Skills, Knowledge, and Responsibilities (SKR) scores, which is an evaluation of scores based on the classroom observation rubric across stayers, movers, and leavers.[3] The SKR scores are rated on a five-point scale, with 1 indicating "needs improvement" and 5 indicating "exemplary". They found that the average SKR scores were 3.1 for all teachers, 3.1 for stayers, 2.8 for movers, and 3.2 for leavers. They reported that an analysis of variance (ANOVA) rejected the equality of the average SKR scores across groups (alpha level=0.05), which means that there was at least one significant difference among the three groups. However, this does not mean that the TAP programs are more likely to hold more effective teachers and that the less effective teachers would leave. That is, the stayers had lower SKR scores

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[3] Stayers referred to teachers who stayed in schools where they taught in the previous year. Movers are teachers who moved to another school within the district whereas leavers referred to those who left the district altogether, which includes cases of leaving teaching profession, moving to another public school out of the district or teaching in private schools.

than the leavers and higher SKR scores than the movers. Therefore, contrary to the two studies above, there is little evidence that the TAP program in Chicago can hold a certain group of teachers more than any other group.

In a recent peer-reviewed journal, Goldhaber and Walch (2012) reported a mixed effect of an ACP in Denver, the Professional Compensation System for Teachers (ProComp). “When [they] compare voluntary enrollees to teachers in ProComp years who choose to never enroll, the effect is statistically significant and positive in middle school math but not significant in [high school] or [reading]” (Goldhaber & Walch, 2012, p. 1076).

In summary, the four previous studies showed mixed evidence on the relationship between the alternative teacher compensation programs and teacher retention rates (See Table II-1). And the positive relationships were limited in the *first* year of implementation in the two Texas cases. The associations of the ACPs and student achievement were also mixed. Even though the study in Denver found a positive effect in middle school math, the effect of ACPs was insignificant in the other school levels or subjects. In the Texas GEEG case, a negative effect was reported.

< Table II- 1 > Quantitative Studies of the Causal Effect of Teacher Incentive Programs on Teacher Retention Rate and Student Achievement

Study	Sample	Time Span of Study	Effect on overall Teacher Retention	Effect on Student Achievement
Glazerman and Seifullah (2010)	Chicago elementary schools (TAP*, participants and non-participants)	2007–08 to 2008–09	Not significant	Not significant
Goldhaber and Walch (2012)	Student in the Denver public schools (students taught by ProComp** voluntary participant, compulsory participant, and non-participant teachers)	2002–03 to 2009–10	Not Applicable	Positive in middle school math but insignificant in middle school reading, high school math and reading
Springer et al. (2009b)	Texas schools (TEEG*** participants and non-participants)	2006–07 to 2008–09	Not Significant	Not Significant
Springer et al. (2009a)	Texas schools (GEEG**** participants and non-participants)	2005–06 to 2007–08	Positively Significant for the first year of the Program, Not Significant for the second and the third year	Negative*****

* The TAP is the abbreviation for the Teacher Advancement Program

** The ProComp is the abbreviation for the Denver Professional Compensation System for Teachers

*** The TEEG is the abbreviation for the Texas Educator Excellence Grant program

**** The GEEG is the abbreviation for the Governor's Educator Excellence Grant program of Texas

***** The study adopted four analytical models and three sampling groups, and the results were slightly different across models and samplings. This study accepted the results of the fourth model, which employed the most rigorous analytical strategy by including student and school fixed effects and sampling students in all schools participating in the program regardless of the criteria by which a school was participating in the program.

These mixed results regarding the effect of ACPs on teacher retention rates and student achievement make it difficult for policymakers to be conclusive about the effect of ACPs. One reason for the mixed results could be a relatively short implementation period. Among the studies mentioned above, only Goldhaber and Walch's study analyzed an ACP that had been implemented for five years. On the other hand, the other studies examined the effect of ACPs that had been implemented for no more than three years. Considering that teachers would need time to adjust to the new program, more studies are needed for ACP cases implemented for a term longer than three years. This study plans to investigate changes in student achievement and teacher retention rates in Minnesota public schools over eight years, 2003–2010. Because Q Comp began in the 2005–2006 school year, the research period makes it possible to examine up to five years of the Q Comp implementation effect.

The mixed results, moreover, could be associated with variations of ACPs in the components and institutional settings where ACPs have been implemented. The mixed nature of the evidence calls for further exploration of which factors may facilitate or impede the effect of ACPs. This study extends the literature by looking specifically at school type, charter school or traditional public school, as a factor to consider when examining the effects of ACPs. Charter schools have been reported to have more difficulties than traditional public schools in supporting teachers' professional development (Stuit & Smith, 2012). Considering the assumption of diminishing marginal utility in economics, ACPs could have higher incremental effects in charter school environments than in traditional public schools.

This study aimed to contribute to research on ACPs, giving empirical evidence on the effects of Minnesota Q Comp, for which there has been little reported research. This study also examined whether duration of implementation and school type is related to the effect of ACPs, which could help to explain the mixed effects that previous studies have reported.

Consideration of duration of implementation and school type could provide valuable and practical information for policymakers considering implementation of ACPs. Based on the information, they could estimate how much time it would take to see a visible effect of ACPs. Also, the information could help policymakers to establish priorities in their implementation of ACPs across different types of schools.

Previous studies have examined the effect of ACPs on teacher retention and student achievement (Glazerman & Seifullah, 2010; Springer, Lewis, Podgursky, Ehlert, Gronberg, et al., 2009; Springer, Lewis, Podgursky, Ehlert, Taylor, et al., 2009). There are, however, few empirical studies that have been done on the impact of Minnesota Q Comp.

Moreover, there are few studies on the distinctive effects of Q Comp associated with school types, e.g., charter school versus TPS. Therefore, this study contributed to the studies on ACPs by providing information on the Minnesota case and the differential impact of ACPs based on school type. It gives practical information for school policymakers and charter school leaders in the implementation of ACPs.

The study could also contribute to teacher retention research. As DeAngelis and Presley (2011) found, there still remains much unexplained variation in teacher retention in spite of the many studies on school factors, including urbanicity and characteristics of student population. Based on this finding, they argued that school policymakers should identify and provide more targeted assistance to schools beyond urbanicity and student demographics. This study could contribute to teacher retention research by exploring the possibility that charter schools could be a target group for staffing-related assistance and that ACPs could be an effective way to assist that target group.

Research Questions

In summary, this study proposes four research questions on the effect of ACPs. All questions are analyzed at the school level.

(1) Do alternative compensation programs (ACPs) for teachers have an impact on schools' overall teacher retention rates?

(2) Do alternative compensation programs (ACPs) for teachers have an impact on schools' retention rates of teachers with three or more years of teaching experience?

(3) Do alternative compensation programs (ACPs) for teachers have an impact on student achievement?

(4) Do alternative compensation programs (ACPs) for teachers have a different impact in charter schools compared to traditional public schools? Specifically:

   a. Do alternative compensation programs have a different impact on the overall teacher retention rates of charter schools compared to traditional public schools?

b. Do alternative compensation programs have a different impact on schools' retention rates of teachers with three or more years of teaching experience in charter schools compared to traditional public schools?
c. Do alternative compensation programs have a different impact on schools' student achievement in charter schools compared to traditional public schools?

The first two questions are about teacher retention rates, and the third question focuses on student achievement. The fourth question repeats the initial three questions and asks whether the impacts are different based on school type, focusing on a comparison between charter schools and traditional public schools. This analysis was done by inclusion of a dummy variable for charter schools and an interaction variable of charter schools and ACP. More description on the equations used is in the discussion of the methods of analysis section of this study.

CHAPTER III: METHOD OF ANALYSIS AND DATA

This study used data from the Minnesota public schools to answer the research questions identified in the previous chapter. Minnesota has implemented an ACP, Quality Compensation (Q Comp), since the 2005–06 academic year. Minnesota is also the state where the first charter school in the United States opened in 1992. Therefore, examining Minnesota can offer useful insight on the effect of ACPs for a relatively long term of implementation and the interaction effect between ACPs and charter schools.

Minnesota Public Schools and Quality Compensation Program

According to an explanation of the Minnesota Office of the Legislative Auditor (MOLA, 2009), Minnesota has developed a Q Comp program based on the experiences of education reform, including professional learning communities (PLCs), standard-based teacher evaluation systems, and financial incentives to improve teacher performance. In other words, the Q Comp program results from multiple streams of education reform, which can explain why the Q Comp program has five components correlated with each other.

Components of Minnesota Q Comp program

With a look at the five components of Q Comp (See Table III-1), we note that the Q Comp program not only compensates teachers based on how their students perform, but also gives incentives to teachers with advancement on the career ladder, professional teacher development, and leadership in the professional development of groups of teachers.

< Table III- 1 > Q Comp Components

	Description
Career Advancement Opportunities	Career advancement opportunities allow teachers to take on leadership roles while retaining a presence in the classroom. These positions typically allow the teacher to continue to teach on a part-time basis. Some opportunities are full time for a limited term, typically no more than one to three years, after which the teacher returns to the classroom.
Professional Development	Under Q Comp, professional development must take place on site, during the school day, and be led by trained teacher leaders.
Teacher Evaluations	Teacher evaluations are conducted several times during the year by a locally trained team using multiple criteria.
Performance-Based Pay	Performance-based pay must be tied to (1) school-wide student achievement, (2) measures of student achievement for a teacher's own students, and (3) teacher evaluations.
Alternative Salary Schedule	Q Comp participants must reform their "steps and lanes" salary schedule so that teachers are no longer automatically rewarded for additional years of experience.

Note. From *Q Comp: Quality compensation for teachers : Evaluation report* by Minnesota Office of the Legislative Auditor, 2009, p. 20.

MOLA (2009) reviewed various examples of how Q Comp schools have been implementing the five components. From the review, they found that Q Comp schools use career advancement opportunities to create leadership position for PLCs, mentor position for new teachers, or data analysts, peer evaluators, and researchers' positions to identify pedagogical best practices. They also reported that the professional development component helps Q Comp schools to "give teachers opportunities to share teaching strategies, analyze student performance, … evaluate or observe other teachers, … discuss educational research and learn new curricula" (p. 22). Certainly, the opportunities identified in this report could be offered in schools with traditional salary schedules. This report, however, showed that Q Comp schools actively used the professional development component to give teachers professional development opportunities. Q Comp schools evaluate their teachers in various ways, including peer observations. The results of teacher evaluations are often used as criteria for the performance-based pay component. Q Comp schools also use school-wide achievement gains or individual teacher-wide achievement gains as criteria for performance-based pay. Q Comp schools are required to reform salary schedule based on performance measures. MOLA (2009) found some Q Comp schools with such a low standard in performance measures that most teachers can move forward almost automatically on the salary schedule. Other Q Comp schools, on the other hand, linked salary increase to the completion of an action-research project, teacher evaluation, or additional responsibilities.

Teachers who were in Q Comp schools showed positive responses on the Q Comp components, especially on the professional development. When MOLA asked teachers in Q Comp schools "how creating leadership positions and career advancement opportunities for teachers has affected the respondent's school district or charter school," 61% of respondents indicated a positive or strongly positive effect. For questions about the effectiveness of professional development programs offered by ACPs, more than half of the respondents agreed that it had a positive or strongly positive effect. Another study also reported that "when teachers spoke positively about Q Comp, they noted most often the support they are receiving to improve their practice" (Wahlstrom et al., 2006, p. 9).

Those results suggest that teachers experiencing Q Comp perceive the ACP to be supportive of their professional development. This supports the assumption that there is a positive relationship between Q Comp and the teacher retention rates of schools.

Funding for Q Comp

Schools participating in the Q Comp program (Q Comp schools) can receive additional revenue of up to $260 per student for the program from state aid and local levies (Minnesota Department of Education, 2010). According to MOLA's (2009) report, Q Comp aid from the state was $260 per student in fiscal year 2006, the first year of implementation, and $190.06 per student in fiscal years 2007, 2008, and 2009. It, however, had decreased to $169 per student from fiscal year 2010 onwards by the 2008 Legislature. MOLA (2009) stated that this reduction in Q Comp aid exacerbated school staff's concern that Q Comp funding would not be continued. Considering that some schools accepted Q Comp in order to have an alternative funding stream (Wahlstrom et al., 2006), this concern could be a barrier against participating in the program.

The local levy for Q Comp is optional. If school districts decided to issue a levy, they can do within a limitation that the total Q Comp fund of state aid and local levy should be less than the maximum amount of $260 × student enrollment. For example, because the state aid was 190.06 per student in 2007, school districts could decide the amount of levy within a range from zero to $69.94 × student enrollment ($260 – $190.06 = $69.94). By law (Minnesota Statutes 2008, 126C.10, subd. 34(a)), charter schools cannot conduct a levy and receive additional state aid based on the average per pupil Q Comp revenue (state aid plus local levy) of all Q Comp schools of the state. According to MOLA's (2009) report, 85% of Q Comp districts in 2008 levied for Q Comp funds, and

94% of the levies were for the maximum amount (i.e., $260 per pupil after adding state aid). Q Comp charter schools in 2008 received an estimated $249.72 per pupil as Q Comp aid from the state.

Q Comp Participation Rates

Beginning with 72 schools in the 2005–06 school year, the number of Q Comp schools increased to 333 in 2009–10 (See Table III-2). The number of Q Comp schools largely increased between the 2005–06 and 2006–07 school years, but the rate of growth has slowed since 2007–08. Although we could speculate that this waning might be related to the reduction of state aid mentioned above, there is no study on the reason for the slowdown.

< Table III- 2 > Participation Rate of Minnesota Public Schools in Q Comp

Academic	Traditional Public School			Charter School		
Year	All*	Q Comp**	% Q Comp	All*	Q Comp**	% Q Comp
2002–03	1,605	0	0.0%	81	0	0.0%
2003–04	1,616	0	0.0%	96	0	0.0%
2004–05	1,622	0	0.0%	116	0	0.0%
2005–06	1,631	67	4.1%	142	5	3.5%
2006–07	1,636	243	14.9%	147	21	14.3%
2007–08	1,648	285	17.3%	160	29	18.1%
2008–09	1,647	297	18.0%	169	35	20.7%
2009–10	1,632	293	18.0%	170	40	23.5%

*The numbers of all traditional public schools and charter schools are from the eighth and seventh column, respectively, in Table III-3 of this study.
**The number of Q Comp schools is counted by author based on annual reports of Q Comp basic aid and total revenue by Minnesota Department of Education (Minnesota Department of Education, 2006b, 2008b, 2009a, 2009b, 2009c).

We also found that charter schools would be more likely to participate in the Q Comp compared to the traditional public schools after 2007–08 (we will describe below the way we use the term, traditional public school, and the way we count the number of schools in this study). The growth rate for Q Comp participation among charter schools largely increased between 2005–06 and 2006–07 as it did among traditional public schools. It also slowed down after 2007–08 but not as much as in traditional public schools.

Identifying Schools of Research Objective

In Table III-2, this study presented the annual Q Comp participation rates. The rates were calculated by this study with a way of counting the number of Minnesota public schools and the term, traditional public schools, was used with a certain operational definition. The way of counting and the definition were related to the identified research objective of this study. Therefore, it is necessary to explain those terms in more detail.

To examine the effect of Q Comp, this study observed Minnesota public schools from the 2002–03 through the 2009–10 academic years. The first year of the Q Comp was the 2005–06 school year. To compare school-level teacher retention rates and student achievement before and after Q Comp implementation, this study observed school-level data in 2002–03, three years before the first Q Comp year, through the 2009–10 academic year, which was the last academic year for which individual school data are available. This research period from 2002–03 to 2009–10 allowed this study to trace the effect of Q Comp for the full five years of implementation of those schools that implemented the program from its beginning in 2005–06.

To create a list of research schools during the research period, this study started from annual reports of student enrollment by gender and ethnicity posted on the MDE website (The MDE website is now posting the data files from 2005–06 to 2009–2010. Data from 2003–04 and 2004–05 were downloaded from the same website in 2010 by author. Data for 2002–03 were obtained through email contact with MDE). From the reports, 16,633 non-charter schools were listed in total (the second column of Table III-3). This includes 2,092 non-charter schools in 2002–03; the number had increased to 2,089 in 2007–08 and then decreased to 2,046 in 2009–10 in the non-charter school sector. On the other hand, there were 1,140 charter schools, including 88 in 2002–03 and 179 in 2009–10 (the third column of Table III-3). As a result, a total of 17,773 schools were listed in the starting point (the fourth column of Table III-3).

< Table III- 3 > Number of Minnesota Schools from the 2002–03 to the 2009–10 Academic Year

Academic	Starting Point			After Consideration of School Classification		
Year	Non-Charter	Charter	Total	TPS*	Charter	Total
2002–03	2,092	88	2,180	1,524	81	1,605
2003–04	2,087	101	2,188	1,520	96	1,616
2004–05	2,091	122	2,213	1,506	116	1,622
2005–06	2,091	149	2,240	1,489	142	1,631
2006–07	2,088	155	2,243	1,489	147	1,636
2007–08	2,089	168	2,257	1,488	160	1,648
2008–09	2,049	178	2,227	1,478	169	1,647
2009–10	2,046	179	2,225	1,462	170	1,632
Total	16,633	1,140	17,773	11,956	1,081	13,037

* TPS: Traditional Public School
Note. The number of schools in this table are counted by author from data file of Minnesota Department of Education (n.d.-a, n.d.-b, n.d.-c, n.d.-d, n.d.-e, n.d.-f, n.d.-g, n.d.-h) with *R* (version 3.0.2) statistical software.

The listed schools in the left panel of Table III-3 not only include public schools offering general education to K-12 graders but also other schools specializing in alternative learning programs, distance learning programs, delinquent and correctional programs, and special education programs. This study focuses on the comparison of the Q Comp effect in general K–12 public schools, excluding the specially classified schools. It is difficult to measure teacher retention rates and student achievement in the same way for those specialized schools as for general schools. For example, teacher retention rates in distance learning programs or student achievement in special education programs would be measured in different ways. Therefore, this study excludes the special types of schools from the analyses.

To exclude the specially classified schools, this study considered the school classification code to focus on general K–12 program schools. The MDE classifies schools into 31 groups based on characteristics of program. As seen in Table III-4, general K–12 education programs were coded as 10 (elementary), 20 (middle), 31 (junior high), 32 (senior high), 33 (secondary), and 40 (elementary and secondary). By contrast, there were schools for students with special needs, for example, special education (code 50), vocational program (code 60), or delinquent student/correctional program (code 70).

Among schools with 10, 20, 31, 32, 33, and 40 classification codes, this study considered district type code to identify "charter schools" and "traditional public schools". Because the MDE assigns 7 to charter schools as their district type code, schools coded as 7 in district type code were considered as charter schools and the other schools were referred to as traditional public schools in this study.

< Table III- 4 > School Site Classification in Minnesota

Code	Classification Description	#of schools in 2011–12
10	Elementary (PK–6)	919
20	Middle School (5–8)	185
31	Junior High (7–8 or 7–9)	35
32	Senior High (9–12)	212
33	Secondary (7–12)	219
40	Elem/Sec Combo (K–12)	18
41	ALC	172
42	ALP	42
43	Private Alternative Program	15
44	Reserved	0
45	Targeted Services	0
46	Distance Learning Program (state approved)	14
50	Special Education	242
51	Special Education ESY (Extended School Year)	0
55	Combined Spec Ed & Voc Ed Program	2
60	Secondary Vocational Program	1
70	Delinquent Student/Correctional Program	12
71	Miscellaneous Program (assignment is now limited)	7
72	Neglected Student Program, Title 1	1
73	Homeless Student Program, Title 1	1
74	Hospital/Medical/Partial Hospitalization Program	10
75	Telecommunications District	0
76	Educational Oversight to Private Residential Care & Treatment	3
77	Educational Oversight to Public Residential Care & Treatment	51
78	Educational Oversight to Private Day Treatment Program	0
79	Educational Oversight to Public Day Treatment Program	22
80	Technical Colleges (PSEO)	0
81	Post Secondary School/Program	0
82	Community & Adult Education Program	0
83	Early Childhood Screening	0
90	Administrative Program	0

Note. From *School site classifications* by Minnesota Department of Education (n.d.-i).

As a result of this consideration, the number of schools included in the analysis was 1,605 in the 2002–03 and 1,632 in the 2009–10 academic year (the fifth column in Table III-3). The number of charter schools was 81 in 2002–03 and 170 in 2009–10 as shown in the sixth column in Table III-3. The numbers of TPS were 1,524 in 2002–03 and 1,462 in 2009–10 (the seventh column in Table III-3). In total, this study had 13,037 cases (the bottom row in Table III-3), which consist of 11,956 TPS cases from 1,620 TPS schools (over 8 years examined) and 1,081 cases from 197 charter schools (over 8 years examined).

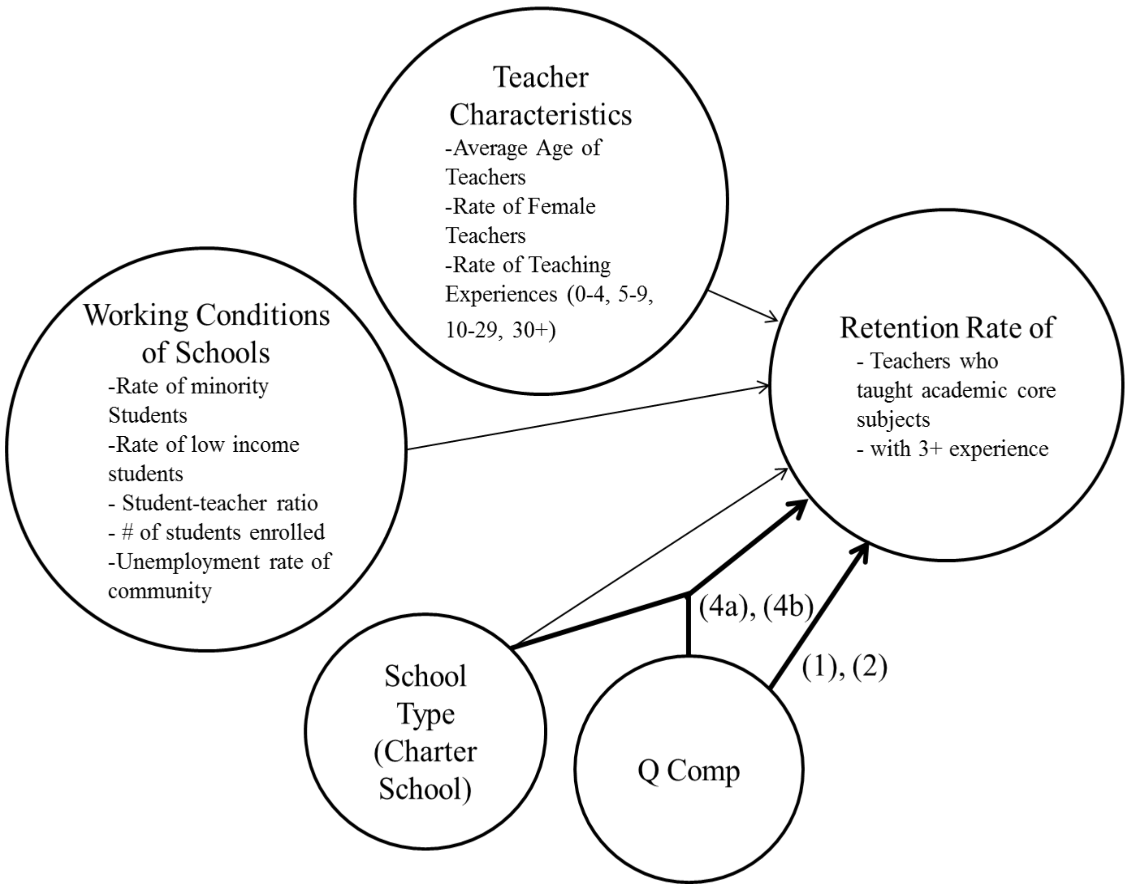
Research Model

The research questions regarding the association between ACPs and teacher retention rate are related to a teacher retention model with the dependent variables capturing overall teacher retention rates and rates for experienced teachers. The third research question is related to student achievement. The fourth research question addresses the interaction effect between school type and Q Comp participation. The *interaction effect* is a statistical term referring to an additional effect of Q Comp on each dependent variable when school type is changed from TPS to charter schools (Agresti & Finlay, 1997; Howell, 2007). The interaction effect will be additionally considered for the models for research questions (1) through (3).

Therefore, two research models are required to answer the four main research questions. The first model, the teacher retention model, is about research question (1), (2), (4a), and (4b). The second model, the student achievement model, addresses research questions (3) and (4c).

Research Model for Teacher Retention

According to previous studies (Hanushek et al., 2004; Imazeki, 2005; Reichardt & Buhler, 2002), teacher retention is a function of characteristics of individual teachers, working conditions of schools, amount of salary, personnel policies of schools, and economic conditions of communities. School type, whether schools are charter schools or not, has also been reported to be associated with teacher retention (Carruthers, 2012; Cowen & Winters, 2012; Stuit & Smith, 2012). Although the previous studies we have referred to are functions of teacher-level analysis, this study assumes that the same factors are present in a teacher retention function for school-level analysis. Based on the teacher retention function, this study illustrates a conceptual model for examining research questions (1), (2), (4a), and (4b) as shown in Figure 1.



[Figure III- 1] Conceptual Model for Teacher Retention Rate Analysis

Retention rate. This study was interested in two dependent variables regarding teacher retention: (1) overall school-level retention rates of teachers who taught academic core subjects in the previous academic year and (2) school-level retention rates of teachers with three or more years of teaching experience. To calculate teacher retention rates, this study compared two subsequent years of teacher lists of a school. Teachers who appeared on both years of teacher lists were considered to be retained in the school in the subsequent year and this study called them “stayers”. Teacher retention rates were calculated by the number of stayers over the number of teachers in the previous school year. For example, school A’s retention rate of 2010 was calculated by the number of teachers who were listed in both the 2009–10 and 2010–11 teacher list (stayers in 2010-11 school year) over the number of teachers who were listed in the 2009–10 teacher list of school A. The dependent variables calculated in this way are continuous variables. Each dependent variable called for an independent analysis.

Based on the previous studies referred to above, four groups of factors were controlled to examine the association between the retention rates and Q Comp: Teacher characteristics at the school level, working conditions of schools, and school type.

Teacher characteristics. According to Kirby and Grissmer (1993), teacher retention is associated with teachers' age. The older teachers are, the more teachers are likely to stay in the teaching profession. They also found that female teachers were more likely to leave the teaching profession than males were as measured in annual leaving rates. When teachers were considered who returned to the teaching profession a few years later, however, there was little difference between male and female teachers in permanent leaving rate. This study is not about permanent retention rates but annual retention rates. Therefore, this study considered gender a characteristic of teachers associated with retention rates. One more teacher characteristic considered in the previous studies is teaching experience. For example, Hanushek et al.'s (2004) study found that teachers with higher levels of experience were less likely to move out of their districts if they stayed in teaching. Additionally, teachers with 31 or more years of teaching experience were more likely to leave the teaching profession. They argued that "as a teacher gains more experience, … the potential gains are frequently limited by restrictions on the transferability of experience credit across districts, affecting salary and other attributes of the job" (Hanushek et al., 2004, p. 332). They also assumed that the higher probability of teachers with 31 or more years of experience in teaching leaving the profession would be related to retirement. This study included teacher characteristic variables aggregated to the school level such as average age and percentage of female teachers in schools. This study also considered the teaching experience of teachers by employing dummy variables that captured the percentage of teachers with 5 to 9, 10 to 29, and 30 or more years of teaching experience. The percentage of teachers with 0 to 4 years of teaching experience was the reference for the dummy variables.

Working conditions of schools. The working conditions of schools that influence teachers' decisions to work in the schools is generally captured by demographic characteristics of students and the student-teacher ratio (Clotfelter et al., 2011; Reichardt & Buhler, 2002). This study also accounted for working conditions by including the percentage of minority students, percentage of low-income students, and student-teacher ratio as Clotfelter et al. (2011) and Reichardt and Buhler (2002) did.

School size was also considered as a school characteristic associated with teacher retention. When a school is very small, teachers may be asked to teach many different courses (Imazeki & Goe, 2009), which may increase teacher dissatisfaction. Therefore, school size as measured by the number of enrolled students was included in the model.

The economic environment of schools is known to be related to teacher retention of schools (Hanushek et al., 2004; Reichardt & Buhler, 2002). When the economic environment is good, there are many jobs open to teachers, which could reduce the teacher retention rates of schools. As a proxy for the economic environment of schools, previous studies have used the unemployment rate of communities in which schools are located (Hanushek et al., 2004; Reichardt & Buhler, 2002). This study included unemployment rate of communities in the model.

This study did not include an important indicator of working conditions, the level of monetary compensation (Clotfelter et al., 2011; Hanushek et al., 2004; Imazeki, 2005). Previous studies represented the level of monetary compensation with salary of teachers with zero experience and no graduate degree in single–salary schedule of each school district (e.g., Hanushek et al., 2004). Because of data limitations, however, this study could not consider this characteristic of schools. When this study calculated the average salary of teachers with zero experience and no graduate degree by district, there were many schools with no teachers with zero experience and no graduate degree (i.e., 1,894 of the 12,708 cases (14.9%) analyzed in the retention model had no teachers at the lowest rung of the salary schedule). It would not be missed at random because schools with fewer number of teachers would be more likely to be missed in this variable.

However, omitting this indicator of working conditions would not be problematic in this study because of two reasons. Firstly, the main concern of this study is the effect of ACPs, which is a policy on monetary compensation. Changes in the monetary compensation would be a part of this compensation policy. If we controlled for the changes in the monetary compensation, we would also control for a part of the policy effect.

Secondly, this study adopted a school fixed effects model to control for time-invariant unobservable variables across schools. This study assumed that schools' characteristics related with salary schedules would not be largely changed across years unless they adopted the ACPs. That is, this study considered the characteristic of the salary schedules of schools to be a time-invariant variable, which would be controlled for with consideration of school fixed effects. If my assumption on there being little change in salary schedules across years was realistic, omission of teacher salaries would not be problematic in estimating the effect of Q Comp.

School type. Charter schools are known to be faced with more difficulties in retaining teachers than TPSs. For example, in a recent study using Florida public school data for 2002–2008, Cowen and Winters (2012) found that teachers in charter schools are more likely to leave the teaching profession than those in TPSs. Stuit and Smith (2012) also found an attrition rate gap between teachers in charter schools and those in TPSs in a study using the 2003–2004 Schools and Staffing Survey (SASS) and the 2004–2005 Teacher Follow-up Survey (TFS) of the National Center for Educational Statistics (NCES). They reported that the higher proportions of uncertified and inexperienced teachers in charter sector and poor working conditions could be related to the attrition rate gap. This study considered school type with a categorical variable where TPSs were coded as 0 and charter schools were coded as 1.

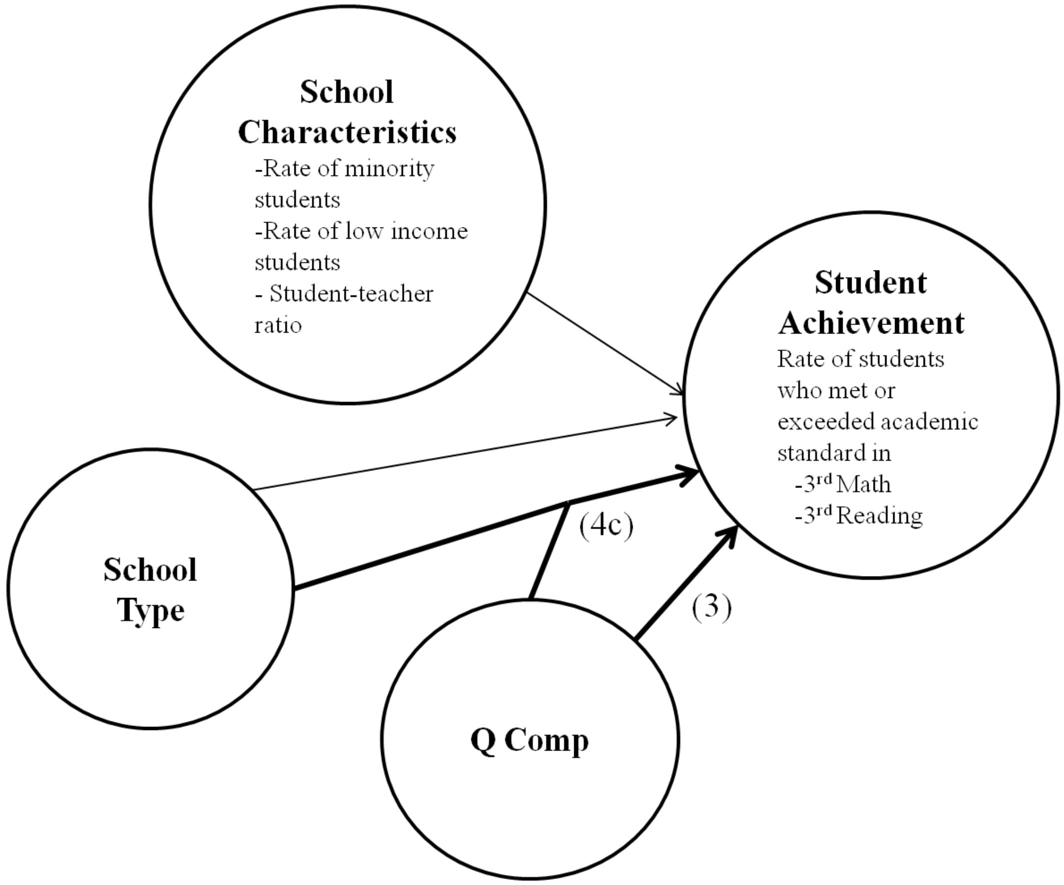
Q Comp program. The main concern of this study was the associations of each dependent variable with the alternative compensation program in Minnesota, Q Comp. After controlling for the previous factors, this study examined the association between the identified dependent variables and Q Comp. The data were examined in two ways. Firstly, this study examined the difference in the retention rate between Q Comp and non-Q comp schools. In this examination, the Q Comp variable was coded as 0 for non-Q Comp schools and 1 for Q Comp schools. Secondly, this study considered the number of years a school has implemented Q Comp. For the research period from 2002–03 to 2009–

10, there were schools that have implemented Q Comp for at most five years (from 2005–06 to 2009–10). This analysis required five dummy variables for years 1, 2, 3, 4, and 5 of implementation. The comparison group was schools that have not implemented Q Comp.

Interaction between school type and Q Comp. Research question (4) was about the distinctive effect of Q Comp when charter schools implemented the program. The interaction term between school type and Q Comp addressed this research question. The coefficient of this term was about the effect of Q Comp when charter schools implemented the program compared to the effect of Q Comp when TPSs implemented it.

Conceptual Model for Student Achievement

Student achievement is known to be a function of student characteristics, teacher characteristics, and school characteristics (e.g., Archibald, 2006). Therefore, the conceptual model for student achievement is illustrated in Figure 2. In the model of this study, student and teacher characteristics were aggregated to the school level for use in the analysis.



[Figure III- 2] Conceptual Model for Student Achievement Analysis

Student achievement. This study used the Minnesota Comprehensive Assessment (MCA) test score to measure student achievement. The MCA is a statewide test implemented since 1998 for the purpose of statewide system accountability. The information from this test is also used to determine proficiency levels in each school and district for the purpose of determining Adequate Yearly Progress (AYP) for the No Child Left Behind legislation (Minnesota Department of Education, 2008a). This study used a school's percentage of students who met or exceeded the Minnesota academic standard as a proxy for the level of student achievement of the school.

This study used the MCA reading and math results to capture the student achievement of schools. The MCA started testing third and fifth grade students on reading, mathematics, and writing subjects in 1998. By 2010, the MCA had been expanded to other grades (3–8th, 10th, and 11th). Test subjects have also changed. Writing has not been tested since 2006, and a test on science has been implemented only since 2008. In the middle of the expansion, reading and math tests for third and fifth grade students have been consistently administered during the period of this study, 2002–03 through 2009–10 (Minnesota Department of Education, 2008a).

This study focused on changes in the MCA results of third graders. The third grade test result is considered to be important because it is associated with high school graduation (e.g., Hernandez, 2011). Therefore, this study observes changes of annual percentage of third grade students who met or exceeded the standard in reading and math MCA tests at the school level.

There was a version change to MCA-II in 2005–06. This change makes it difficult to compare test scores of MCA and MCA-II. This study used the schools' percentage of students who met or exceeded the standard rather than schools' average test scores. Both MCA and MCA-II examined whether a student met the Minnesota Academic Standard of his/her grade for the tested subject. MCA classified student test scores into 5 levels (level 1, 2a, 2b, 3, and 4). Students at or above level 2b were considered to meet the standard (Davison et al., 2004). MCA-II divided students into four proficiency levels. To meet the standard, students must be at or above level 3 (Minnesota Department of Education, 2008a). Even though both exams were used to identify students who were at or above proficiency level, the version change would make a difference in the measurement of student proficiency rates across versions. This study tested the effect of version change by regressing the dependent variable of student achievement on the version of MCA (which was considered as a dummy variable, 0 was for 2002-03, 2003-04, and 2004-05 and 1 was for 2005-06 through 2009-10 cases). In the test, this study found significant effect of version change (in Reading model, b = 0.031680, *s.e.* = 0.004475, $t = 7.08$, $p < 0.01$ and in Mathematics model, b = 0.063360, *s.e.* = 0.004529, $t = 13.99$, $p < 0.01$). To address this problem, this study included year fixed effects that controlled for the effect of version changes as well as any other year-specific characteristics.

Considering year fixed effects would not be the best way to address this problem. The best way would be if the two versions were vertically aligned across the proficiency level (Case & Zucker, 2005) and if we included information of the MCA-II version scores corresponding to the MCA version cutoff scores. This study, however, did not have information on this. Under the limited situation of this study, considering year fixed effects would be a good way to address this problem.

To test the possibility of the year fixed effects to control for the version change effects, this study did a comparison as follows. First, this study considered the estimated difference between the two versions of MCA, the coefficient of the first version in the regression analysis mentioned above, 0.031680 in reading and 0.06336 in math, and the effect of the version change. Second, the estimated version change effect was subtracted from each dependent variable only for MCA-II cases, 2005-06 through 2009-10 to correct the dependent variables for the version change. Third, the student achievement models with the corrected dependent variable and with the not-corrected dependent variable were analyzed. Fourth, the estimated coefficients and standard errors of the coefficients were compared between the two models.

Through the comparison, this study found the coefficients and standard errors of independent variables were same except for the year dummies of 2006, 2007, 2008, 2009, and 2010, when new version of MCA was administered. The differences between the two models in the coefficient of year 2006, year 2007, year 2008, year 2009, and year 2010 were 0.03168 in reading model and 0.06336 in math model, which was the estimated effect of version change. Moreover, the standard errors of year 2006, year 2007, year 2008, year 2009, and year 2010 were the same in both models. From the results, considering year fixed effects could be a possible alternative for controlling for the estimated effect of version change under the limited context of this study.

In summary, this study used third grade mathematics and reading test results on MCA tests (MCA-II since 2005–06) to measure the level of student achievement of schools. The school’s percentage of students at or above proficiency level in each test represents the level of student achievement of schools.

School characteristics. Aggregated student characteristics, percentage of minority students, and percentage of low-income students were included in the model. The effect of class size on student achievement has been known to be the most promising in grades K–3 (Robinson, 1990). Since this study used third grade scores, this additional control may be warranted. To capture class size at the school level, this study considered student-teacher ratio, which was calculated by the student enrollment over the total full time equivalent (FTE) of teachers.

School type. This study considered two types of schools, traditional public schools (TPS) and charter schools. This study identified charter schools with a categorical variable where TPSs were coded as 0 and charter schools were coded as 1.

Q Comp program. Research question (3) of this study focused on the associations of student achievement with Q Comp implementation. After controlling for the previous factors, this study examined the association between the dependent variables and Q Comp. As in the retention rates model, the examination was operated in two ways: (1) only considering Q Comp implementation and (2) considering the years of implementation of Q Comp.

Interaction between school type and Q Comp. The research question (4c) was about the interaction effect between school type and Q Comp. By addressing this interaction effect, this study compared the effect of Q Comp on student achievement when charter schools implemented the program to the effect of Q Comp when TPSs implemented it.

Analytical Technique

This study used a data set of Minnesota public schools to examine the effect of the Q Comp program. By regressing each dependent variable on independent variables, this study estimated coefficients of each independent variable. The main concern of this study was the coefficient of Q Comp implementation.

To increase precision in estimation, this study used longitudinal data where variables of Minnesota public schools are repeatedly measured. The longitudinal design observed multiple occasions before and after treatment. This multiple observation increases the number of observation so that the temporality of the data is reduced (Heck, 2004). Therefore, this study observes repeatedly measured school data for eight years, at least three years before the Q Comp and up to five years after the Q Comp was initially implemented.

Omitted Variables Problem

In addition to increasing the number of observations, a longitudinal study, such as this one, makes it possible to control for unobserved heterogeneity (Cameron, 2005). As mentioned in the previous section, the Q Comp is a voluntary program, so the Q Comp treatment was not randomly assigned across schools. Without random assignment of schools to research groups, this study may face an omitted variables bias problem, which would produce biased estimates (Cook, 2002; Heckman, 1979).

In other words, because Q Comp was not randomly assigned across schools, it is possible that there are significant differences in the average school between Q Comp and non-Q Comp schools. For example, let us think about the quality of principal leadership of schools. Leadership quality is known to be associated with teacher retention and achievement (Leithwood & Louis, 2012). The quality of principal leadership is also possibly correlated with Q Comp participation. This is because schools' participation in Q Comp is based on the agreement of teachers (MOLA, 2009). Considering that sharing a vision with members, and leading them to achieve the vision are components of a good leader (Leithwood & Louis, 2012), the quality of principal leadership could be correlated with the Q Comp participation of schools. If so, this unobserved variable, the quality of leadership, would be correlated with Q Comp participation, a key independent variable of this study, and dependent variables, teacher retention rate and student achievement. Not considering the variable in the analysis model, the coefficient of the Q Comp participation would be biased (Cook, 2002). However, data on leadership quality, and changes therein, were difficult to observe for the years examined, so this study did not include it in the analytical model.

Addressing Selection Bias: School Fixed Effects (Within Model)

To control for unobserved compounding variables, this study considers school fixed effects. School fixed effects are considered by using school-mean-deviation scores rather than raw scores of dependent and independent variables (Allison, 2009).

School-mean-deviation scores refer here to scores extracted by the mean score of each school. For example, let us consider the school-mean-deviation score of teacher retention rates. Each school has raw data of teacher retention rate across eight time points (from 2002–03 to 2009–10) in the data of this study. Each school has its mean score of the eight time points' raw scores. The mean score can be called school-mean-teacher-retention rate. If a raw score of a school in a year are subtracted by its school-mean-teacher-retention rate, the result refers here to the school-mean-deviation score of the school in that year.

In this way, all dependent and independent variables were transformed into the school-mean-deviation scores and used in the analyses. In practice, this study used *plm package* in *R* (Croissant et al., 2013) rather than constructing the deviation scores and then analyzing them. By the argument, *model="within"*, the *plm* function of the package automatically produced school-mean-deviation scores and then used them to estimate coefficients.

Year Fixed Effects

In addition to school fixed effects, this study also considered year fixed effects controlling for year-specific characteristics in teacher retention rate and student achievement. For example, considering teacher retention rates are more likely to be high when the economic condition is bad (Hanushek et al., 2004; Reichardt & Buhler, 2002), the nationwide economic recession after 2008 might be associated with higher teacher retention rates. Also, the version change of MCA as mentioned in the previous section could be related to student achievement.

Comparison of models with and without year fixed effects by *F* test was employed to evaluate the need of year fixed effects term. The *pFtest* function in the *plm package* in *R* (Croissant et al., 2013) was used to do the comparison. Comparison of the models show that models with year fixed effects terms were significantly different from models without year fixed effects terms ($F(7, 10966) = 6.2083$, $p < .001$ for the retention model on research questions (1) and (4a), $F(7, 10918) = 5.8987$, $p < .001$ for the retention model about research questions (2) and (4b), $F(7, 5790) = 136.4683$, $p < .001$ in math achievement model, and $F(7, 5802) = 67.738$, $p < .001$ in reading achievement model about research questions (3) and (4c)). Based on these results, this study included year fixed effects term in the models to control for year-specific differences across years.

Variability of Coefficient of Q comp Variable

This study examined the variability of coefficient of Q Comp variable, whether or not the effect of Q Comp could vary across schools. That is, by adopting a random effect on the coefficient to build a linear mixed model (LMM; Long, 2011), this study examined the possibility of that variation.

Comparison of models with and without the random effect term by ANOVA test was also employed to evaluate the possibility. The *lmer* function in *lme4 package* (Bates, Maechler, & Bolker, 2013) and *anova* function in *R* was used to do this. The result was $\chi^2(2) \approx 0$, p ≈ 1 for all models. It showed that including the random effect would not make a difference, which could be interpreted that it would not be needed. Therefore, this study did not consider the variability of the coefficient of the Q Comp variable.

Autocorrelation

Autocorrelation means “correlation between members of a series of observations ordered in time” (Gujarati & Sangeetha, 2008, p. 452), which could happen in analysis of panel data. Because autocorrelation would affect estimation of standard errors of estimated coefficients in the analysis, the significance test for coefficients would be problematic (Gujarati & Sangeetha, 2008). To address this problem, after analysis of each model, this study tested the possibility of autocorrelation by the Breusch-Godfrey/Wooldridge test, using the *pbgtest* function in the *plm* package of *R* (Croissant et al., 2013). When autocorrelation was detected, this study adopted the Newey-West method to correct standard errors, which is “known as HAC (heteroscedasticity- and autocorrelation-consistent) standard errors” (Gujarati & Sangeetha, 2008, p. 494). Even though this method is known to be inappropriate for small samples, this study included a large number of schools so it was appropriate to use this method. The *coeftest* function with *vcovHC* and *method=”arellano”* in the *lmtest* package in *R* was used to correct standard errors, which is known to be appropriate for fixed effects model (Croissant & Millo, 2008).

Bias from Inclusion of Non-Q Comp Schools

The current study included data from non-Q Comp schools, together with pre-intervention data from Q Comp schools, to estimate the level of Q Comp school performance prior to the implementation of Q Comp. An alternative strategy would have relied entirely on the pre-intervention data from Q Comp schools to estimate the level of Q Comp school performance prior to the implementation of Q Comp. The alternative approach would use each Q Comp school as its own matched control and may be considered preferable because this form of matching ensures that the treatment and control schools are matched on unobserved covariates as well as observed covariates. In comparison, the non-Q Comp schools may differ from the Q Comp schools along unobserved covariates. In comparison to the alternative strategy, the strategy employed in the current study may produce biased estimates. The direction of bias is unknown and suggests caution in interpreting the estimates of Q Comp effects (see Appendix for more discussion of this issue).

Equations for Analysis

Based on the discussion above, the equation for the teacher retention model is as follows:

$$R_{st}^{*} = \mu_{t} + \beta T_{st}^{*} + \gamma WC_{st}^{*} + \delta(\mathrm{Q\ Comp}_{st})^{*} + \varepsilon_{st}^{*} \qquad (1)$$

In the model and hereafter, the asterisk marks indicated that the variable was transformed into school-mean-deviation score. The deviation score of the teacher retention rate of school *s* in school year *t*, R^*_{st}, was a function of year fixed effects, μ_t, deviation scores of aggregated teacher characteristics, T^*_{st}, working condition of school, WC^*_{st}, and Q Comp implementation, $(\text{Q Comp}_{st})^*$. Regarding research question (1), this study is interested in the coefficient matrix of δ, whether it was significantly positive or not. If the Q Comp variable was considered, the δ was a 1×1 matrix, which represented the difference between Q Comp and non-Q Comp schools. When the Q Comp variable was considered in terms of length of implementation, the δ was a 1×5 matrix, which estimated the difference between non-Q Comp schools and first, second, third, fourth, and fifth year of implementation, respectively.

The equation for research question (2) was similar to equation (1), as indicated below:

$$\text{ExpR}^*_{st} = \mu_t + \beta T^*_{st} + \gamma WC^*_{st} + \delta(\text{Q Comp}_{st})^* + \varepsilon^*_{st} \qquad (2)$$

The only difference was the dependent variable. The deviation score of experienced teacher retention rate of school *s* in school year *t*, ExpR^*_{st}, was used here, and the research focus was also on the coefficient matrix of δ, whether it was significantly positive or not.

Below is the equation for the student achievement model:

$$A^*_{st} = \mu_t + \beta SC^*_{st} + \delta(\text{Q Comp}_{st})^* + \varepsilon^*_{st} \qquad (3)$$

The dependent variable was the deviation score on rate of students who were on or above the proficiency level of school *s* in school year *t*. It was regressed on year fixed effects, μ_t, deviation scores of aggregated school characteristics, SC^*_{st} and Q Comp implementation, $(\text{Q Comp}_{st})^*$. The research focus was also on the coefficient matrix, δ.

For the research question (4), one additional variable of school type was added in the equation (1) ~ (3). School type was a time-invariant variable so its transformation into school-mean-deviation scores makes the value of all schools zero. Therefore, as Allison (2009) recommended, the difference between charter schools and traditional public schools in the dependent variables were represented by the interaction terms of year fixed effects and charter school, $\mu_t(\text{School Type}_s)$. The interaction of Q Comp and charter school, $(\text{School Type}_s)(\text{Q Comp}_{st})^*$, indicated the charter school-specific Q Comp effect.

$$R^*_{st} = \mu_t + \beta T^*_{st} + \gamma WC^*_{st} + \zeta\mu_t(\text{School Type}_s) + \delta(\text{Q Comp}_{st})^* + \eta(\text{School Type}_s)(\text{Q Comp}_{st})^* + \varepsilon^*_{st} \quad (4a)$$

$$ExpR^*_{st} = \mu_t + \beta T^*_{st} + \gamma WC^*_{st} + \zeta\mu_t(\text{School Type}_s) + \delta(\text{Q Comp}_{st})^* + \eta(\text{School Type}_s)(\text{Q Comp}_{st})^* + \varepsilon^*_{st} \quad (4b)$$

$$A^*_{st} = \mu_t + \beta SC^*_{st} + \zeta\mu_t(\text{School Type}_s) + \delta(\text{Q Comp}_{st})^* + \eta(\text{School Type}_s)(\text{Q Comp}_{st})^* + \varepsilon^*_{st} \quad (4c)$$

According to research questions (4a) ~ (4c), the coefficient matrix of η as well as δ were estimates of interest. The η represented whether or not a charter school-specific effect of Q Comp existed when compared to that of a traditional school. When the Q Comp variable was considered in terms of length of implementation, the η indicated an effect of Q Comp on charter schools with a given years of Q Comp implementation when compared to the other schools.

Data Sources

This study will use data mainly from the website of the Minnesota Department of Education (MDE, http://education.state.mn.us/MDE/index.html). Teacher-level data, which are used in identifying site information of each teacher in each school year, were from the database of the Pioneer Press (hereafter, it is called MDE-P, http://extra.twincities.com/car/schoolsalaries/default.aspx). It has posted information on assigned school and subjects and amount of salary of licensed educators in Minnesota public schools. The source of the Pioneer Press database was constructed from “MDEDATAB Assignment, AssignDesc and OrgUnit tables” (Minnesota Department of Education, n.d.-j) and “MDEDATAB Employment and OrgUnit tables” (Minnesota Department of Education, n.d.-k) of the Minnesota Department of Education. The data represented the status as of October 1st of every school year. A summary of variables and their data sources is provided in Table III-5.

< Table III- 5 > Variables and Data Sources of This Study

Variables	Data Sources	Data Description
Retention rates of school	Calculated by Author with MDE-P data	Portion of teachers staying in the school from the previous year to a given year (Continuous variable)
Retention rates of experienced teachers in school	Calculated by Author with MDE-P data	Portion of experienced teachers staying in the school from the previous year to a given year (Continuous variable)
Schools' portion of student who met or exceeded standard in 3rd Math MCA	MCA result files from the MDE website	Portion of students who was at level 2b, 3, or 4 in 3rd grade Math MCA or at level 3 or 4 in 3rd grade Math MCA-II test (Continuous variable)
Schools' portions of student who met or exceeded standard in 3rd Reading MCA test	MCA result files from the MDE website	Portion of students who was at level 2b, 3, or 4 in 3rd grade Reading MCA or at level 3 or 4 in 3rd grade Reading MCA-II (Continuous variable)
Teachers' average age of school	Teacher Demographics files	(Continuous variable)
Proportion of female teachers	Teacher Demographics files	Female teacher FTE (full-time equivalent) over the total teacher FTE (Continuous variable)
Proportion of teachers with teaching experiences of:	Teacher Demographics files	(Continuous variable)
5-9 years		Portion of teachers with 5-9 years teaching experience
10-29 years		Portion of teachers with 10-29 years teaching experience
30 or more years		Portion of teachers with 30 or more years teaching experience

(Continued)

(Continued)

Variables	Data Sources	Data Description
Proportion of minority students	Student Enrollment by gender and ethnicity files	Number of non-white students over total students (Continuous variable)
Proportion of low income students	Student Enrollment by special populations files	Number of students receiving Free or Reduced Price Lunch program over total students (Continuous variable)
Student-teacher ratio	Teacher Demographics files, Student Enrollment by special populations files	Number of total students over total teacher FTE (Continuous variable)
Number of enrolled students	Student Enrollment by gender and ethnicity files	Number of total students enrolled in a given school (Continuous variable)
School Type (Charter school or not)	Student Enrollment by gender and ethnicity files	Binary variable (1 for schools with district type code 7, 0 otherwise)
Unemployment rate of community	Website of Minnesota Department of Employment and Economic Development	(Continuous variable)
Q Comp participating schools	Q Comp Revenue files from the MDE website	Binary variable (1 if the school was implementing Q Comp in a given year, and 0, otherwise)
Duration of Q Comp:	Q Comp Revenue files from the MDE website	
1 Year of Q Comp		Binary variable (1 if the school was implementing Q Comp for 1 year including a given year, and 0, otherwise)
2 Years of Q Comp		Binary variable (1 if the school was implementing Q Comp for 2 years including a given year, and 0, otherwise)
3 Years of Q Comp		Binary variable (1 if the school was implementing Q Comp for 3 years including a given year, and 0, otherwise)
4 Years of Q Comp		Binary variable (1 if the school was implementing Q Comp for 4 years including a given year, and 0, otherwise)
5 Years of Q Comp		Binary variable (1 if the school was implementing Q Comp for 5 years including a given year, and 0, otherwise)

MDE-P Data and Overall Retention Rate of Teachers

The overall retention rate of teachers was calculated by the author based on information from the MDE-P data. Those data files listed all licensed staff in Minnesota public schools with their identification number and information on which school they worked in and which subjects they taught in every year. Based on the information, this study identified the number of teachers who taught core subjects (by school and by school year, from 2002–03 to 2009–10. Then, by a comparison with the next school year's teacher list, this study identified teachers who stayed in their schools in the next school year (stayers) and the number of stayers in each school, from 2003–04 to 2010–11. This identification made it possible to calculate retention rates across schools and time. For example, the 2003 retention rate of a given school was the number of teachers who were assigned in the given school in the 2003–04 school year list out of the teachers who were assigned in the school in the 2002–03 school year. The retention rates of experienced teachers were calculated by the same process for the different group of teachers, teachers with three or more years of experience.

Other Data Sources

An important dependent variable of this study is the results of the Minnesota Comprehensive Assessment (MCA) exams. Annual MCA result reports were posted on the MDE website. The reports contained information on the number of students who took the exam and the number of students in each proficiency level (MCA grouped students by five levels and MCA-II by four levels). This information allowed this study to calculate the percentage of third grade students who met or exceeded mathematics or reading standards at the school level.

The MDE publicized files annually on teacher demographics aggregated at the school level on its website (http://education.state.mn.us/MDE/index.html). Those files included information on average teacher age, the number of teachers full time equivalent (teacher FTE), female teacher FTE, and the number of teachers by teaching experiences of 0-4, 5-9, 10-14, 15-19, 20-24, 25-29, 30 years or more. This study used the information to get the average teacher age, the portion of female teachers, and the portion of teachers with teaching experiences of 5-9, 10-29, and 30 years or more.

Not only teacher demographics, but also information on student demographics at the school level was posted on the MDE website. Those files provided information on the percentage of minority students, the percentage of free or reduced lunch price recipients, and the total number of students enrolled in a given school. The teacher demographic and student enrollment files in the MDE website were also used to calculate the student-teacher ratio.

This study measured the economic condition of communities using the unemployment rates of the economic development region in which the schools are located. The unemployment rate data were available on the website of the Minnesota Department of Employment and Economic Development (http://www.positivelyminnesota.com/apps/lmi/laus/).

Annual reports of Q Comp revenue on the MDE website from fiscal year 2006 to 2010 gave information on schools that received Q Comp revenue in an academic year. Based on the information, this study identified whether or not a school implements Q

Comp in an academic year. A possible problematic case would be schools that are listed in school districts reported as Q Comp districts in an academic year but are not listed in the Q Comp revenue reports. This study assumed that if schools did not receive Q Comp revenue, they could not implement Q Comp appropriately. Districts, however, could support Q Comp implementation in those schools. Therefore, this study considered all schools within school districts that were reported to be Q Comp districts in an academic year as Q Comp schools in that year. Exceptions were Minneapolis public schools and Roseville public schools. Those districts are not permitted to have district-wide Q Comp plans but may contain individual school-wide plans. Therefore, schools in Minneapolis and Roseville school districts were considered as Q Comp schools only when they were listed in the Q Comp revenue reports.

CHAPTER IV: EFFECT ON TEACHER RETENTION RATE

This chapter reports the finding from the analyses of the teacher retention model and consists of two sections: The first section is on overall teacher retention rate, and the second is on retention rate of experienced teachers. The first section gives answers to research question (1), the Q Comp effect on overall teacher retention rate, and (4a), the Q Comp effect on overall teacher retention rate that is distinctive in charter schools. The second section is about research question (2), the Q Comp effect on retention rate of experienced teachers, and research question (4b), the Q Comp effect on retention rate of experienced teachers specific to charter schools.

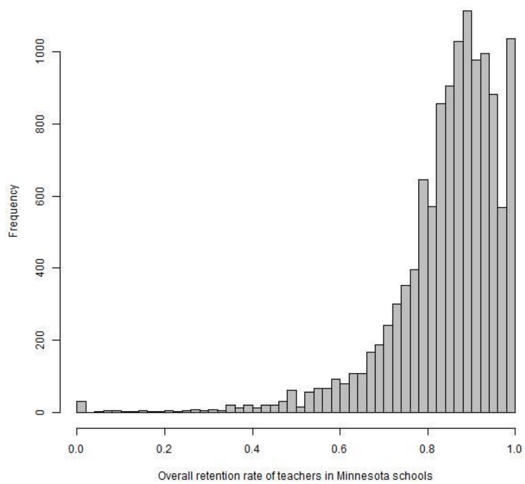
Overall Teacher Retention Rate of Minnesota Schools

The analysis includes 12,708 cases that consist of 1,734 schools for eight years, from 2003 to 2010. For the research period, the annual average teacher retention rates were stable around 0.84, with a low of 0.83 in 2006 and 2007 and a high of 0.86 in 2004, 2009, and 2010 (See Table IV-1(a)). After transforming retention rates to the school-mean-deviation scores by subtracting each school's average over time, which is the dependent variable actually used after controlling for school fixed effects (Croissant & Millo, 2008), the annual means moved around 0.00 from -0.01 to 0.01, but the trend looked similar (See Table IV-1(b)). That is, it decreased to -0.01 in 2006 and 2007 but increased to 0.01 in 2009 and 2010.

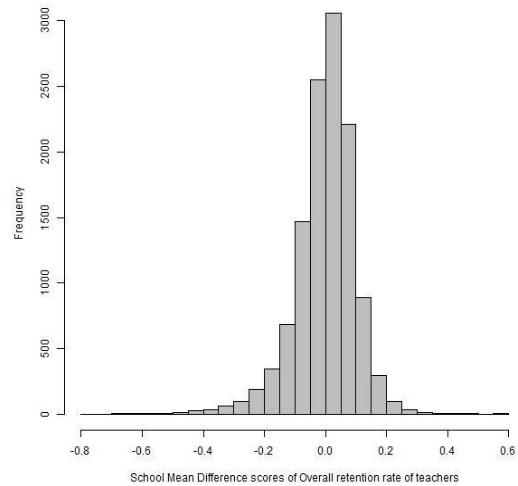
< Table IV- 1 > Trend in Overall Teacher Retention Rates of Minnesota Schools: 2003–2010

		(a) Retention Rates		(b) School Mean Deviation Scores	
Year	N	Mean	SD	Mean	SD
2003	1,556	0.84	0.14	0.00	0.11
2004	1,585	0.85	0.13	0.00	0.10
2005	1,583	0.84	0.14	0.00	0.11
2006	1,587	0.83	0.15	-0.01	0.11
2007	1,606	0.83	0.14	-0.01	0.11
2008	1,625	0.84	0.15	0.00	0.11
2009	1,599	0.85	0.13	0.01	0.11
2010	1,567	0.86	0.13	0.01	0.11
Total	12,708	0.84	0.14	0.00	0.11

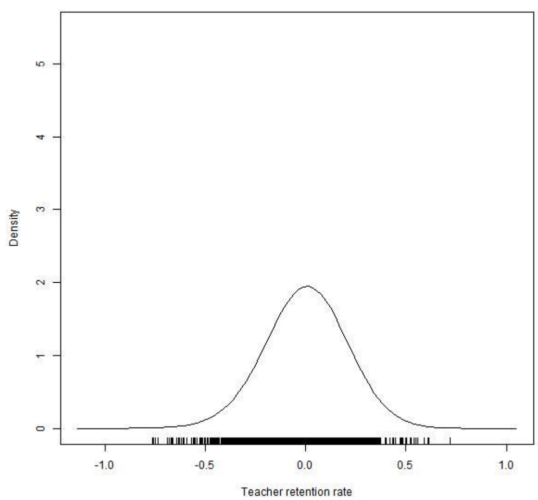
The distribution of the teacher retention rates across cases was different from the normal distribution, negatively skewed, and the frequency was inflated around 1.0 (See Figure IV-1 (a)). Because this study used a fixed effects model by *plm package* of R (Croissant et al., 2013), the dependent variable was subtracted by the school's average over time in the actual analysis (Croissant & Millo, 2008). This time-process made the distribution of the dependent variable similar to the normal distribution (See Figure IV-1(b) and 1(c)). According to quantile-quantile plot (Q-Q plot, see Figure IV-1(d)), however, it seemed to be a heavy-tailed distribution rather than the normal distribution, which has more observations in two sides than the normal curve. The violation of normality assumption in regression does not prevent the estimation of unbiased coefficients. It, however, is related with estimating standard errors for the coefficients, which would make *t*-test on coefficients problematic in small samples (Gujarati & Sangeetha, 2008, pp. 346–347). This analysis, however, was with a large sample (N = 12,708), which would make this violation not very problematic.



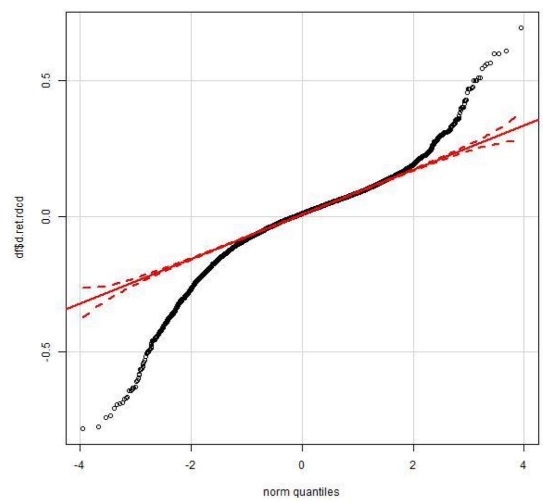
(a) Teacher Retention Rate of MN Schools



(b) Teacher Retention Rate of MN Schools (School-Mean-Deviated)



(c) Density Plot for Teacher Retention Rate of MN Schools (School-Mean-Deviated)



(d) Q-Q Plot for Teacher Retention Rate of MN Schools (School-Mean-Deviated)

Note. Figures were generated by the *sm package* (Bowman & Azzalini, 2014) and the *car package* (Fox et al., 2014) in the software R

[Figure IV- 1] Distribution of Overall Teacher Retention Rate across Schools

Correlation Analysis

This study performed two correlation analyses for the variables considered with values before and after transforming into school-mean-deviation scores (See Table IV-2 and IV-3). In the result with values before the transformation, the retention rate was significantly but not strongly correlated with the characteristics of teacher composition. It was positively correlated with the average age of teachers (R= 0.11, $p < 0.01$) and the rate of experienced teachers (R= 0.06, $p < 0.01$ for 5 to 9 years of experience, R= 0.17, $p < 0.01$ for 10 to 29 years of experience, and R= 0.14, $p < 0.01$ for 30 and more years of experience). On the other hand, it was negatively correlated with the percentage of female teachers (R= -0.03, $p < 0.05$).

The retention rate was also correlated with school characteristics representing teachers working conditions. That is, it was negatively correlated with percentage of minority students (R= -0.24, $p < 0.01$) and FRL students (R= -0.18, $p < 0.01$). It was, however, positively correlated with student-teacher ratio (R= 0.02, $p < 0.05$)[4], which is the opposite direction from what this study expected.

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[4] The correlation coefficient is too little to be considered practically important in spite of its statistical significance. However, the direction was opposite from what this study expected so that this study described this relationship more fully.

< Table IV- 2 > Correlation Matrix of Variables in Overall Teacher Retention Rate Analysis

	Mean	S.D.	Retention Rate	Average Teacher Age	Female Teacher Rate	5-9 years of experience	10-29 years of experience	30 + years of experience
Average Teacher Age	41.26	4.01	0.11**					
Female Teacher Rate	0.73	0.17	-0.03**	0.08**				
Rate of teachers with								
5-9 years of experience	6.72	6.03	0.06**	-0.27**	-0.13**			
10-29 years of experience	14.95	11.26	0.17**	0.10**	-0.10**	0.63**		
30 + years of experience	3.30	3.23	0.14**	0.27**	-0.12**	0.34**	0.53**	
Student-Teacher Ratio	16.00	6.90	0.02*	0.01	0.00	0.11**	0.15**	0.10**
Minority Student Rate	0.22	0.26	-0.24**	-0.10**	0.13**	0.15**	-0.02	-0.19**
FRL Student Rate	0.36	0.23	-0.18**	0.07**	0.09**	-0.14**	-0.24**	-0.24**
#Enrollment	503.02	411.38	0.12**	-0.08**	-0.16**	0.81**	0.90**	0.59**
Unemployment Rate	5.19	1.54	0.09**	0.07**	-0.04**	-0.15**	-0.03*	-0.07**
School Type+	0.08	0.27	-0.27**	-0.36**	-0.04**	-0.17**	-0.34**	-0.29**
Q Comp+	0.10	0.30	-0.01	-0.09**	0.08**	0.12**	0.17**	-0.02

(Continued)

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	S-T Ratio	Minority Student Rate	FRL Student Rate	#Enrollment	Unemployment Rate	School Type
Average Teacher Age						
Female Teacher Rate						
Rate of teachers with						
5-9 years of experience						
10-29 years of experience						
30 + years of experience						
Student-Teacher Ratio						
Minority Student Rate	-0.03**					
FRL Student Rate	-0.20**	0.73**				
#Enrollment	0.23**	-0.01	-0.30**			
Unemployment Rate	-0.06**	-0.08**	0.16**	-0.09**		
School Type[+]	-0.01	0.28**	0.24**	-0.24**	-0.03**	
Q Comp[+]	0.04**	0.08**	-0.05**	0.16**	0.06**	0.02*

* $p < .05$; ** $p < .01$

Note 1. This Pearson correlation matrix was developed by the *psych* package in *R* (Revelle, 2014).
Note 2. Because school type and Q Comp ([+] marked) were nominal variables, point-biserial correlation coefficients were calculated for them, which were calculated by biserial.cor function of the *ltm* package in R (Rizopoulos, 2013).

The opposite direction could be interpreted with other correlation coefficients. The student-teacher ratio was negatively correlated with percentage of minority students or free or reduced lunch program eligible students. Because the variables were also correlated with teacher retention rates, those associations could confound the relationship between the student-teacher ratio and teacher retention rates, which would result in associations between the variables being in the opposite direction from what was expected.

Further, the retention rate was negatively correlated with school type, a key variable related to the research question ($R = -0.27$, $p < 0.01$). As reported in previous studies, Minnesota charter schools seem to face more difficulty in retaining their teachers than traditional public schools. Minnesota charter schools also showed a lower average age of teachers and have higher portions of less experienced teachers. Moreover, they seemed to serve a higher percentage of minority and low-income students, which suggest that charter schools may have working conditions characterized by the literature as difficult. In turn, these more challenging conditions may make it more likely that teachers leave the school.

Finally, the retention rate was not significantly correlated with Q Comp implementation or the length of Q Comp implementation, which is a main concern of this study. Moreover, the direction of the correlations between the retention rates and Q Comp were negative, which was the opposite from the expectation of this study.

However, considering school fixed effects affected correlations among the variables. After transforming all variables to deviation scores, this study examined correlations among the transformed variables again (Compare Table IV-3 to IV-2).

< Table IV- 3 > Correlation Matrix of deviation-scored Variables in Overall Teacher Retention Rate Analysis

	Mean	S.D.	Retention Rate	Average Teacher Age	Female Teacher Rate	5-9 years of experience	10-29 years of experience	30 + years of experience
Average Teacher Age	0.00	1.87	-0.03**					
Female Teacher Rate	0.00	0.05	0.00	0.00				
Rate of teachers with								
5-9 years of experience	0.00	2.28	-0.02*	-0.17**	-0.02*			
10-29 years of experience	0.00	2.59	-0.01	0.12**	0.02*	-0.33**		
30 + years of experience	0.00	1.51	-0.05**	0.21**	-0.09**	0.08**	-0.12**	
Student-Teacher Ratio	0.00	5.01	0.05**	0.09**	0.01	-0.04**	-0.05**	0.00
Minority Student Rate	0.00	0.04	0.02*	-0.01	0.06**	-0.15**	0.16**	-0.28**
FRL Student Rate	0.00	0.05	0.00	0.00	0.05**	-0.14**	0.12**	-0.27**
#Enrollment	0.00	51.29	-0.02	-0.07**	-0.04**	0.34**	0.26**	0.21**
Unemployment Rate	0.00	1.20	0.05**	-0.03**	0.09**	-0.17**	0.22**	-0.24**
School Type+	NA	NA	NA NA	NA	NA	NA	NA	NA
Q Comp+	0.00	0.23	0.02*	-0.01	0.07**	-0.13**	0.18**	-0.18**

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	S-T Ratio	Minority Student Rate	FRL Student Rate	#Enrollment	Unemployment Rate	School Type
Average Teacher Age						
Female Teacher Rate						
Rate of teachers with						
5-9 years of experience						
10-29 years of experience						
30 + years of experience						
Student-Teacher Ratio						
Minority Student Rate	-0.03**					
FRL Student Rate	-0.05**	0.55**				
#Enrollment	0.06**	-0.08**	-0.10**			
Unemployment Rate	-0.03**	0.25**	0.37**	-0.05**		
School Type+	NA	NA	NA	NA	NA	
Q Comp+	-0.02*	0.31**	0.22**	0.00	0.18**	NA

* *p* < .05; ** *p*< .01

Note 1. This Pearson correlation matrix was developed by the *psych* package in *R* (Revelle, 2014).
Note 2. School Type (+ marked) was a time-invariant characteristic of school so it was excluded from this correlation analysis.

The transformation resulted in many correlations becoming weaker and not statistically significant. For example, the retention rate deviation score was no longer associated significantly with percentage of female teachers, percentage of FRL students, and number of enrolled students. On the other hand, it became significantly correlated with Q Comp implementation even though the size of the correlation is very weak (R= 0.02, $p < 0.05$).

The correlation analysis showed that Q Comp was related to the within-school changes in the retention rate of teachers even though the relationship was not strong. Because Q Comp was correlated with some of the other independent variables that were also associated with the retention rate, multiple regression analysis with consideration of school and year fixed effects was employed to examine the relationship of Q Comp with the retention rate after controlling for the other variables. The results are presented in the next section.

One more interesting correlation is that of Q Comp with school type before the data was transformed (Because school type is a time-invariant variable, we cannot calculate it after transformation). The association was weak but statistically significant before-transformation analysis (See Table IV-2, R= 0.02, $p < 0.05$). It could be interpreted that charter schools would be more likely to participate in Q Comp.

Overall, the sizes of correlation coefficients were small — only a few correlation coefficients were bigger than 0.3. Specifically, the correlation coefficients related with teacher retention rates became smaller after the school-mean-deviation score transformation. This implies that variables considered in this study could explain the *between* school differences in the retention rate better than *within* school differences. This distinction is discussed more fully in Chapter 6.

Effect of Q Comp on Teacher Retention Rate

As stated in the Chapter 3, this study examined the effect of Q Comp on teacher retention rate. The Q Comp implementation was considered as a binary variable (Yes = 1, No = 0, Table IV-4(A)). It also included the year fixed effects term because a model comparison between with and without the year fixed effects term meant that including the term would be more valid ($F(7, 10966) = 6.2083$, $p < 0.001$). Contrary to the correlation analysis, the association of changes in the teacher retention rate with Q Comp implementation was not significant (b = 0.0072, *s.e.* = 0.0050, $t = 1.4404$, $p > 0.10$).

It might take time for schools to enjoy the effect of Q Comp on the teacher retention rate. When the analysis considered the length of implementation of this study (See Table IV-4(B)), the Q Comp effect was not significant until the fifth implementation year (b = 0.0632, *s.e.* = 0.0148, $t = 4.2817$, $p < 0.01$). It could be interpreted that schools implementing Q Comp for five years would be higher in teacher retention rate by 6.32-percentage points than the other schools that did not have 5 years of Q Comp implementation when the other conditions are the same.

One more interesting finding is that the R^2 was very small ($R^2_{Model\ A} = 0.0124$ and $R^2_{Model\ B} = 0.0135$). It can be interpreted that this model would explain only around 1% of the within-school variations of teacher retention rate. This is a limitation of this study, which will be discussed in more detail in Chapter 6 of this study.

< Table IV- 4 > Result of Analysis on Overall Teacher Retention Rate Model

	(A) Q Comp - Binary			(B) Q Comp - Period		
	Estimate		S.E.	Estimate		S.E.
Year 2004	0.0013		0.0042	0.0014		0.0042
Year 2005	-0.0050		0.0048	-0.0050		0.0048
Year 2006	-0.0130	*	0.0054	-0.0131	*	0.0055
Year 2007	-0.0184	**	0.0055	-0.0185	**	0.0055
Year 2008	-0.0132	*	0.0058	-0.0134	*	0.0059
Year 2009	0.0040		0.0063	0.0041		0.0064
Year 2010	0.0036		0.0122	0.0038		0.0122
Average Teacher Age	-0.0007		0.0011	-0.0007		0.0011
Female Teacher Rate	-0.0203		0.0429	-0.0206		0.0428
Rate of teachers with						
5-9 experiences	-0.0013	*	0.0005	-0.0013	**	0.0005
10-29 experiences	-0.0019	**	0.0006	-0.0020	**	0.0006
30 + experiences	-0.0045	**	0.0009	-0.0045	**	0.0009
S-T Ratio	0.0011	**	0.0004	0.0011	**	0.0004
Minority Student Rate	0.0869		0.0554	0.0884		0.0556
FRL Student Rate	-0.0862		0.0458	-0.0882	.	0.0458
#Enrollment	0.0000		0.0000	0.0000		0.0000
Unemployment Rate	0.0007		0.0030	0.0006		0.0030
Q Comp	0.0072		0.0050			
1 Year Q Comp				0.0076		0.0062
2 Years Q Comp				0.0081		0.0069
3 Years Q Comp				0.0092		0.0075
4 Years Q Comp				-0.0058		0.0091
5 Years Q Comp				0.0632	**	0.0148
R^2	0.0124			0.0135		

* *p* < .05; ** *p*< .01

Note 1. Models (A) and (B) were analyzed by the *plm* function in the *plm* package of *R* (Croissant et al., 2013).

Note 2. In the Breusch-Godfrey/Wooldridge test on the result of the analysis, using the *pbgtest* function in the *plm package of R* (Croissant et al., 2013), result that there would present serial autocorrelation ($\chi^2(1)$ = 104.8374, $p < 0.01$ for the Model (A) and ($\chi^2(1)$ = 103.6093, $p < 0.01$) for the Model (B)). All standard errors were corrected by Newey-West method using the *coeftest* function with *vcovHC* and *method=”arellano”* in the *lmtest package* of *R*.

Effect of Q Comp in Charter Schools

In the next step, this study added the interaction effect terms of time and school type as well as Q Comp implementation and school type. This is to get answers for the research question 4(a), the distinctive effect of Q Comp on teacher retention rates in charter schools.

Firstly, charter schools had significantly higher teacher retention rates in 2009 (b= 0.1153, *s.e.* = 0.0371, $t = 3.1122$, $p < 0.01$) and 2010 (b= 0.1122, *s.e.* = 0.0378, $t = 2.9717$, $p < 0.01$) than traditional public schools (See Table IV-5(A)). As seen in the correlation analysis summarized in Table IV-2, Minnesota charter schools have been challenged with a lower teacher retention rate than traditional schools. When other conditions were the same, however, Minnesota charter schools had higher teacher retention rates in 2009 and 2010 than non-charter schools, which was positive sign for charter schools. We discussed this topic more fully in Chapter 6.

Secondly, Q Comp implementation was not significantly associated with teacher retention rate in traditional schools (b = 0.0081, *s.e.* = 0.0049, $t = 1.6312$, $p > 0.10$) or in charter schools (for Q Comp: School Type (Charter) term, b = -0.0233, *s.e.* = 0.0270, $t = -0.8618$, $p > 0.10$). This result of no significant association is consistent with the result of the previous analysis summarized in Table IV-4(A).

< Table IV- 5 > Result of Analysis on Overall Teacher Retention Rate Model: School Type Focused

	(A) Q Comp - Binary		(B) Q Comp - Period	
	Estimate	S.E.	Estimate	S.E.
Year 2004	-0.0015	0.0040	-0.0015	0.0040
Year 2005	-0.0079	0.0044	-0.0078	0.0044
Year 2006	-0.0168 **	0.0051	-0.0167 **	0.0051
Year 2007	-0.0210 **	0.0052	-0.0212 **	0.0053
Year 2008	-0.0162 **	0.0054	-0.0157 **	0.0054
Year 2009	-0.0042	0.0060	-0.0037	0.0060
Year 2010	-0.0043	0.0121	-0.0046	0.0121
Average Teacher Age	-0.0008	0.0012	-0.0008	0.0012
Female Teacher Rate	-0.0194	0.0419	-0.0207	0.0419
Rate of teachers with				
5-9 experiences	-0.0015 **	0.0005	-0.0015 **	0.0005
10-29 experiences	-0.0018 **	0.0006	-0.0018 **	0.0006
30 + experiences	-0.0049 **	0.0009	-0.0048 **	0.0009
S-T Ratio	0.0011 **	0.0004	0.0011 **	0.0004
Minority Student Rate	0.0913	0.0571	0.0931	0.0575
FRL Student Rate	-0.0906 *	0.0449	-0.0946 *	0.0449
#Enrollment	0.0000	0.0000	0.0000	0.0000
Unemployment Rate	0.0007	0.0030	0.0007	0.0030
Year 2004:School Type (Charter)	0.0590	0.0336	0.0589	0.0337
Year 2005:School Type (Charter)	0.0601	0.0343	0.0599	0.0343
Year 2006:School Type (Charter)	0.0698	0.0371	0.0709	0.0371
Year 2007:School Type (Charter)	0.0584	0.0351	0.0605	0.0353
Year 2008:School Type (Charter)	0.0631	0.0367	0.0589	0.0368
Year 2009:School Type (Charter)	0.1153 **	0.0371	0.1139 **	0.0370
Year 2010:School Type (Charter)	0.1122 **	0.0378	0.1163 **	0.0384
Q Comp	0.0081	0.0049		
Q Comp: School Type (Charter)	-0.0233	0.0270		
1 Year Q Comp			0.0120 *	0.0054
2 Years Q Comp			0.0042	0.0069
3 Years Q Comp			0.0072	0.0074
4 Years Q Comp			-0.0005	0.0090
5 Years Q Comp			0.0720 **	0.0158
1 Year Q Comp: School Type (Charter)			-0.0532	0.0376
2 Years Q Comp: School Type (Charter)			0.0230	0.0318
3 Years Q Comp: School Type (Charter)			0.0064	0.0395
4 Years Q Comp: School Type (Charter)			-0.0789	0.0480
5 Years Q Comp: School Type (Charter)			-0.1053 *	0.0486
R^2	0.0172		0.0194	

* $p < .05$; ** $p < .01$

Note 1. Models (A) and (B) were analyzed by the *plm* function in the *plm* package of *R* (Croissant et al., 2013).

Note 2. In the Breusch-Godfrey/Wooldridge test on the result of the analysis, using the *pbgtest* function in the *plm package of R* (Croissant et al., 2013), result that there would present serial autocorrelation ($\chi^2(1) = 102.8335$, $p < 0.01$ for the Model (A) and ($\chi^2(1) = 100.6787$, $p < 0.01$) for the Model (B)). All standard errors were corrected by Newey-West method using the *coeftest* function with *vcovHC* and *method="arellano"* in the *lmtest package* of *R*.

Thirdly, when the Q Comp variable was examined by length of time implemented and interactions of year and charter school were considered (See Table IV-5(B)), schools with one year of implementation of Q Comp had higher retention rates than the other schools (b = 0.0120, *s.e.* = 0.0054, t = 2.2127, $p < 0.05$). This is different in Table IV-4(B) where interactions of year and charter school were not considered. Moreover, on average, schools that implemented Q Comp for 5 years had 7.2 percentage points higher overall teacher retention rates than the other schools (b= 0.0720, *s.e.* = 0.0212, t = 3.3917, $p < 0.01$).

Fourthly, charter schools that implemented Q Comp for 5 years had overall teacher retention rates that were 10.5 percentage points lower than other schools (b= -0.1053, *s.e.* = 0.0628, t = -1.6756, $p > 0.05$). This finding is opposite to the expectations of this study that charter schools might have more gains from Q Comp because of the assumption of diminishing marginal utility.

Effect of Q Comp on Retention Rate of Experienced Teachers

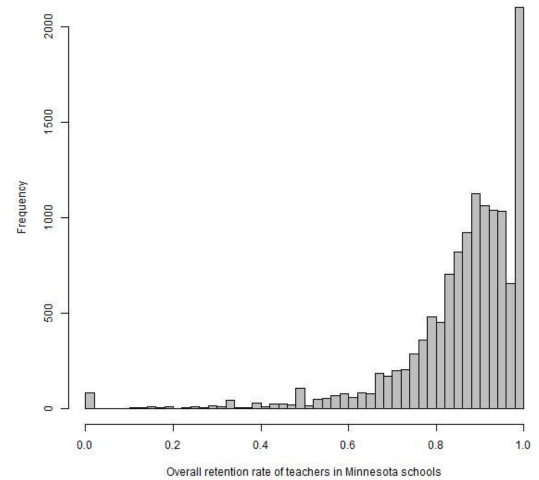
The research question (2) of this study is focusing on the retention rate of teachers with three or more years of teaching experience. To get an answer for the research question, this study calculated retention rate of experienced teachers. The analysis includes 12,657 cases, which consist of 1,731 schools for the eight years of the research period. Compared to the 12,708 cases that consist of 1,734 schools in the previous analysis (about overall teacher retention rate), the case size of this analysis is decreased by 51.

For the research period, the annual retention rates of experienced teachers were stable around 0.86 (See Table IV-6(a)). The overall mean was higher than the overall teacher retention rates of 0.84 (Compare to Table IV-1(a)), and annual retention rates were lower in 2006 and 2007 and higher in 2009 and 2010 than in the previous years, which is similar to the pattern of the overall teacher retention rates. After transformation to school-mean-deviation scores, a similar trend appeared.

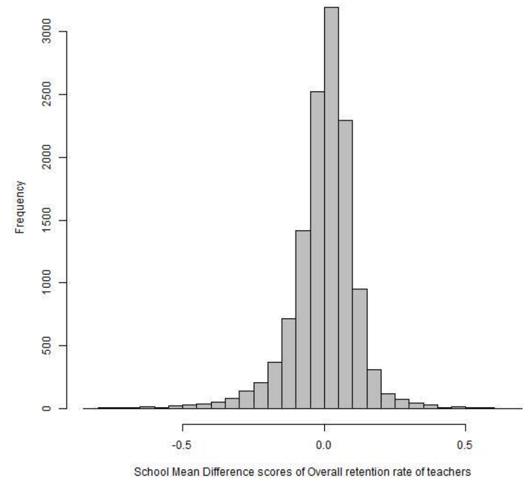
< Table IV- 6 > Trend in Experienced Teacher Retention Rates of Minnesota Schools: 2003–2010

		(a) Retention Rates		(b) School-Mean-Deviation Scores	
Year	N	Mean	SD	Mean	SD
2003	1,551	0.86	0.14	0.00	0.12
2004	1,579	0.86	0.14	0.00	0.11
2005	1,574	0.86	0.14	0.00	0.11
2006	1,581	0.85	0.15	-0.01	0.11
2007	1,601	0.85	0.15	-0.01	0.12
2008	1,618	0.86	0.16	0.00	0.12
2009	1,590	0.87	0.14	0.01	0.12
2010	1,563	0.87	0.13	0.01	0.11
Total	12,657	0.86	0.14	0.00	0.11

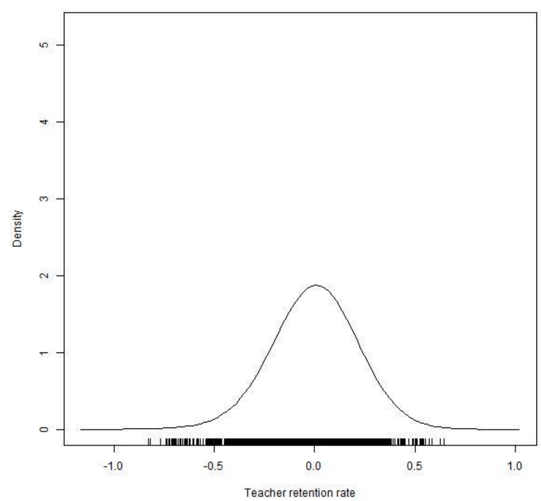
The distribution of the retention rate of experienced teachers across cases was negatively skewed and the frequency was very high around1.0 (See Figure IV-2 (a)). This school-mean-deviation scores dependent variable, however, was close to the normal distribution as in the overall teacher retention rate analysis (See Figure IV-2(b) and 2(c)). According to quantile-quantile plot (Q-Q plot, see Figure IV-2 (d)), however, it seemed to be a heavy-tailed distribution, which is similar to the distribution of overall teacher retention rate. Because this analysis employed a large sample (N = 12,657), this violation was not highly problematic (Gujarati & Sangeetha, 2008).



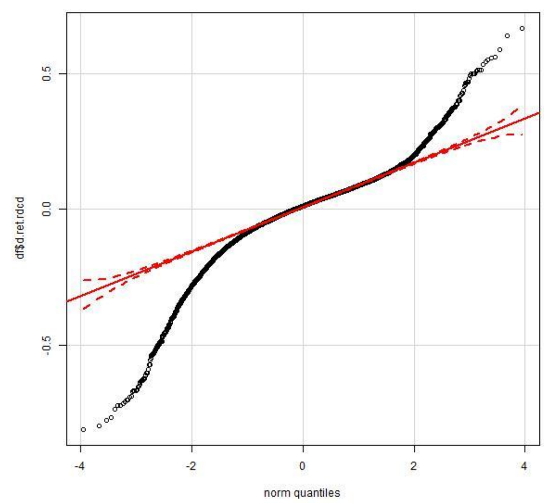
(a) Experienced Teacher Retention Rate of MN Schools



(b) Experienced Teacher Retention Rate of MN Schools (School-Mean-Deviated)



(c) Density Plot for Experienced Teacher Retention Rate of MN Schools (School-Mean-Deviated)



(d) Q-Q plot for Experienced Teacher Retention Rate of MN Schools (School-Mean-Deviated)

Note. Figures were generated by the *sm package* (Bowman & Azzalini, 2014) and the *car package* (Fox et al., 2014) in the software R

[Figure IV- 2] Distribution of Experienced Teacher Retention Rate Across Schools

Correlation Analysis

The correlation analysis showed that the retention rate of experienced teachers was significantly but weakly correlated with school characteristics (See Table IV-7). It was positively correlated with the average age of teachers ($R = 0.06$, $p < 0.01$) and rate of experienced teachers ($R= 0.05$, $p < 0.01$ for 5 to 9 years of experience, $R= 0.15$, $p < 0.01$ for 10 to 29 years of experience, and $R= 0.12$, $p < 0.01$ for 30 and more years of experiences). It was, however, negatively correlated with percentage of female teachers ($R = -0.03$, $p < 0.01$), negatively correlated with percentage of minority students ($R = -0.24$, $p < 0.01$) and FRL students ($R = -0.18$, $p < 0.01$), and positively correlated with number of student enrolled ($R = 0.11$, $p < 0.01$) and unemployment rate of the community ($R = 0.07$, $p < 0.01$). The result is similar to the correlation analysis for overall teacher retention rate summarized in Table IV-2.

< Table IV- 7 > Correlation Matrix of Variables in Experienced Teacher Retention Rate Analysis

	Mean	S.D.	Retention Rate	Average Teacher Age	Female Teacher Rate	5-9 years of experience	10-29 years of experience	30 + years of experience
Average Teacher Age	41.454	3.659	0.06**					
Female Teacher Rate	0.724	0.166	-0.03**	0.08**				
Rate of teachers with								
5-9 years of experience	6.73	6.03	0.05**	-0.27**	-0.13**			
10-29 years of experience	15.00	11.25	0.15**	0.1**	-0.10**	0.63**		
30 + years of experience	3.31	3.23	0.12**	0.27**	-0.12**	0.34**	0.53**	
Student-Teacher Ratio	15.976	3.277	0.01	0.02*	0.00	0.12**	0.15**	0.11**
Minority Student Rate	0.206	0.243	-0.24**	-0.10**	0.13**	0.15**	-0.02	-0.19**
FRL Student Rate	0.346	0.212	-0.18**	0.07**	0.09**	-0.14**	-0.24**	-0.24**
#Enrollment	504.2411.5822		0.11**	-0.09**	-0.17**	0.81**	0.90**	0.59**
Unemployment Rate	5.202	1.553	0.07**	0.07**	-0.04**	-0.15**	-0.03**	-0.07**
School Type^{+}	0.042	0.200	-0.25**	-0.36**	-0.05**	-0.16**	-0.33**	-0.28**
Q Comp^{+}	0.106	0.308	0.00	-0.09**	0.08**	0.12**	0.17**	-0.03**

(continued)

(continued)

	S-T Ratio	Minority Student Rate	FRL Student Rate	#Enrollment	Unemployment Rate	School Type
Average Teacher Age						
Female Teacher Rate						
Rate of teachers with						
5-9 years of experience						
10-29 years of experience						
30 + years of experience						
Student-Teacher Ratio						
Minority Student Rate	-0.03**					
FRL Student Rate	-0.21**	0.73**				
#Enrollment	0.24**	-0.01	-0.30**			
Unemployment Rate	-0.06**	-0.08**	0.16**	-0.09**		
School Type+	-0.02	0.28**	0.24**	-0.24**	-0.03**	
Q Comp+	0.04**	0.08**	-0.05**	0.16**	0.06**	0.02**

* $p < .05$; ** $p < .01$

Note 1. This Pearson correlation matrix was developed by the *psych* package in *R* (Revelle, 2014).

Note 2. Because school type and Q Comp (+ marked) were nominal variables, point-biserial correlation coefficients were calculated for them, which were calculated by biserial.cor function of the *ltm* package in R (Rizopoulos, 2013).

The retention rate of experienced teachers was also significantly correlated with school type ($R = -0.25$, $p < 0.01$). It could be interpreted that charter schools would face more difficulties in retaining experienced teachers than traditional schools, in the same way it is harder for charter schools to retain teachers overall.

Finally, the retention rate was not significantly correlated with Q Comp implementation ($R = 0.00$, $p > 0.10$), which is a main concern of this study. Q Comp implementation was correlated with other school characteristics that were correlated with the retention rate of experienced teachers. After considering school fixed effects, however, the correlation became significant and positive, although very weak ($R = 0.03$, $p < 0.01$, See Table IV-8).

< Table IV- 8 > Correlation Matrix of Deviation-Scored Variables in Experienced Teacher Retention Rate Analysis

	Mean	S.D.	Retention Rate	Average Teacher Age	Female Teacher Rate	5-9 years of experience	10-29 years of experience	30 + years of experience
Average Teacher Age	0.00	1.83	-0.10**					
Female Teacher Rate	0.00	0.05	0.01	0.00				
Rate of teachers with								
5-9 years of experience	0.00	2.28	-0.02*	-0.17**	-0.02*			
10-29 years of experience	0.00	2.59	-0.02	0.12**	0.02*	-0.33**		
30 + years of experience	0.00	1.51	-0.06**	0.22**	-0.10**	0.08**	-0.12**	
Student-Teacher Ratio	0.00	4.87	0.04**	0.10**	0.00	-0.04**	-0.05**	0.00
Minority Student Rate	0.00	0.04	0.02*	-0.01	0.06**	-0.15	0.16**	-0.28**
FRL Student Rate	0.00	0.05	0.01	0.00	0.06**	-0.14**	0.12**	-0.27**
#Enrollment	0.00	51.36	-0.01	-0.07**	-0.04**	0.34**	0.26**	0.21**
Unemployment Rate	0.00	1.20	0.05**	-0.03**	0.09**	-0.17**	0.22**	-0.24**
School Type+			NA	NA	NA	NA	NA	NA
Q Comp+	0.00	0.23	0.03**	-0.01	0.07**	-0.13**	0.18**	-0.18**

(continued)

(continued)

	S-T Ratio	Minority Student Rate	FRL Student Rate	#Enrollment	Unemployment Rate	School Type
Average Teacher Age						
Female Teacher Rate						
Rate of teachers with						
5-9 years of experience						
10-29 years of experience						
30 + years of experience						
Student-Teacher Ratio						
Minority Student Rate	-0.04**					
FRL Student Rate	-0.06**	0.55				
#Enrollment	0.07**	-0.09**	-0.10**			
Unemployment Rate	-0.03**	0.25**	0.37**	-0.05**		
School Type[+]	NA	NA	NA	NA	NA	
Q Comp[+]	-0.02*	0.31**	0.22**	0.00	0.18**	NA

* $p < .05$; ** $p < .01$

Note 1. This Pearson correlation matrix was developed by the *psych* package in *R* (Revelle, 2014).
Note 2. School Type ([+] marked) was a time-invariant characteristic of school so it was excluded from this correlation analysis.

Effect of Q Comp on Retention Rate of Experienced Teachers

The result of the analysis of the effect of Q Comp on the retention rate of experienced teachers was similar to the results of the overall teacher retention rate model (Compare Table IV-9 to Table IV-4). Q Comp was not significantly associated with the retention rate of experienced teachers (b = 0.0098, *s.e.* = 0.0053, $t = 1.8425$, $p > 0.05$). The Q Comp effect, however, was significant in the fifth implementation year (for five years Q Comp in Table IV-9(B), b = 0.0463, *s.e.* = 0.0144, $t = 3.2159$, $p < 0.01$). It could be interpreted that schools implementing Q Comp for five years had teacher retention rates that were4.63 percentage points higher than the other schools when the other conditions are the same. Even though the size of the coefficient is smaller than it is in the overall teacher retention rate analysis (Compare b= 0.0463 in Table IV-9 to b= 0.0632 in Table IV-4), Q Comp had an effect on retaining experienced teachers.

< Table IV- 9 > Result of Analysis on Retention Rate of Experienced Teacher Model

	(A) Q Comp - Binary		(B) Q Comp - Period	
	Estimate	S.E.	Estimate	S.E.
Year 2004	-0.0014	0.0045	-0.0014	0.0045
Year 2005	-0.0065	0.0048	-0.0065	0.0048
Year 2006	-0.0187**	0.0055	-0.0187**	0.0055
Year 2007	-0.0231**	0.0056	-0.0232**	0.0056
Year 2008	-0.0141*	0.0059	-0.0142*	0.0059
Year 2009	0.0025	0.0067	0.0025	0.0067
Year 2010	-0.0009	0.0130	-0.0007	0.0129
Average Teacher Age	-0.0051**	0.0010	-0.0051**	0.0010
Female Teacher Rate	0.0203	0.0427	0.0202	0.0427
Rate of teachers with				
5-9 experiences	-0.0025**	0.0006	-0.0025**	0.0006
10-29 experiences	-0.0025**	0.0005	-0.0025**	0.0005
30 + experiences	-0.0050**	0.0009	-0.0050**	0.0009
S-T Ratio	0.0009**	0.0003	0.0009**	0.0003
Minority Student Rate	0.0436	0.0581	0.0448	0.0583
FRL Student Rate	-0.0401	0.0504	-0.0414	0.0504
#Enrollment	0.0001	0.0000	0.0001	0.0000
Unemployment Rate	-0.0005	0.0032	-0.0005	0.0032
Q Comp	0.0098	0.0053		
1 Year Q Comp			0.0104	0.0069
2 Years Q Comp			0.0098	0.0071
3 Years Q Comp			0.0121	0.0084
4 Years Q Comp			0.0004	0.0091
5 Years Q Comp			0.0463**	0.0144
R^2	0.0204		0.0208	

* $p < .05$; ** $p < .01$

Note 1. Models (A) and (B) were analyzed by the *plm* function in the *plm* package of *R* (Croissant et al., 2013).

Note 2. In the Breusch-Godfrey/Wooldridge test on the result of the analysis, using the *pbgtest* function in the *plm package of R* (Croissant et al., 2013), result that there would present serial autocorrelation ($\chi^2(1) = 120.1686$, $p < 0.01$ for the Model (A) and ($\chi^2(1) = 119.8321$, $p < 0.01$) for the Model (B)). All standard errors were corrected by Newey-West method using the *coeftest* function with *vcovHC* and *method="arellano"* in the *lmtest package* of *R*.

Effect of Q Comp in Charter Schools

This study added the interaction effect terms of time and school type as well as Q Comp implementation and school type. This is to get answers for the research question 4(b), the distinctive effect of Q Comp on retention rates of experienced teachers in charter schools. The main results described below are very similar to the results of the overall teacher retention rate in the previous section.

Firstly, charter schools in 2009 had retention rates of experienced teachers that were 10.18 percentage points higher than the other schools included in the analysis (See Table IV-10, b = 0.1018, *s.e.* = 0.0197, $t = 5.1594$, $p < 0.01$). Charter schools in 2010 also showed significant differences in the retention rates of experienced teachers, compared to the other schools (b = 0.0957, *s.e.* = 0.0200, $t = 4.7821$, $p < 0.01$).

Secondly, Q Comp implementation was not significantly associated with the retention rate of experienced teachers (b = 0.0085, *s.e.* = 0.0050, $t = 1.7161$, $p > 0.05$) and had no specific effect in charter schools (b = -0.0007, *s.e.* = 0.0340, $t = -0.0215$, $p > 0.05$). This is consistent with the result of the overall teacher retention rate analysis seen in Table IV-5(A).

< Table IV- 10 > Result of Analysis on Retention Rate of Experienced Teachers Model: School Type Focused

	(A) Q Comp -Binary		(B) Q Comp - Period	
	Estimate	s.e.	Estimate	s.e.
Year 2004	-0.0034	0.0041	-0.0033	0.0041
Year 2005	-0.0093 *	0.0045	-0.0092 *	0.0045
Year 2006	-0.0188 ***	0.0052	-0.0188 ***	0.0052
Year 2007	-0.0241 ***	0.0053	-0.0243 ***	0.0054
Year 2008	-0.0168 **	0.0055	-0.0165 **	0.0055
Year 2009	-0.0053	0.0063	-0.0048	0.0063
Year 2010	-0.0077	0.0127	-0.0081	0.0127
Average Teacher Age	-0.0053 ***	0.0011	-0.0053 ***	0.0011
Female Teacher Rate	0.0175	0.0415	0.0170	0.0415
Rate of teachers with				
5-9 experiences	-0.0027 ***	0.0006	-0.0027 ***	0.0006
10-29 experiences	-0.0024 ***	0.0005	-0.0023 ***	0.0005
30 + experiences	-0.0053 ***	0.0009	-0.0052 ***	0.0009
S-T Ratio	0.0010 **	0.0003	0.0010 **	0.0003
Minority Student Rate	0.0527	0.0599	0.0551	0.0604
FRL Student Rate	-0.0435	0.0497	-0.0461	0.0497
#Enrollment	0.0000	0.0000	0.0000	0.0000
Unemployment Rate	-0.0006	0.0032	-0.0005	0.0032
Year 2004:School Type (Charter)	0.0400	0.0429	0.0399	0.0429
Year 2005:School Type (Charter)	0.0531	0.0416	0.0530	0.0417
Year 2006:School Type (Charter)	0.0179	0.0434	0.0187	0.0435
Year 2007:School Type (Charter)	0.0302	0.0392	0.0326	0.0393
Year 2008:School Type (Charter)	0.0501	0.0419	0.0477	0.0418
Year 2009:School Type (Charter)	0.1018 *	0.0430	0.0977 *	0.0431
Year 2010:School Type (Charter)	0.0957 *	0.0431	0.0994 *	0.0439
Q Comp	0.0085	0.0050		
Q Comp: School Type (Charter: 1)	-0.0007	0.0340		
1 Year Q Comp			0.0116 *	0.0057
2 Years Q Comp			0.0070	0.0069
3 Years Q Comp			0.0053	0.0072
4 Years Q Comp			0.0029	0.0086
5 Years Q Comp			0.0538 ***	0.0149
1 Year Q Comp: School Type (Charter)			-0.0223	0.0458
2 Years Q Comp: School Type (Charter)			0.0120	0.0387
3 Years Q Comp: School Type (Charter)			0.0608	0.0597
4 Years Q Comp: School Type (Charter)			-0.0466	0.0568
5 Years Q Comp: School Type (Charter)			-0.0923	0.0600
R^2	0.0255		0.0269	

* $p < .05$; ** $p < .01$

Note 1. Models (A) and (B) were analyzed by the *plm* function in the *plm package* of *R*

Note 2. In the Breusch-Godfrey/Wooldridge test on the result of the analysis, using the *pbgtest* function in the *plm package* of *R* (Croissant et al., 2013), result that there would present serial autocorrelation ($\chi^2(1) = 120.1686$, p < 0.01 for the Model (A) and ($\chi^2(1) = 114.9359$, p < 0.01) for the Model (B)). All standard errors were corrected by Newey-West method using the *coeftest* function with *vcovHC* and *method=”arellano”* in the *lmtest package* of *R*.

Thirdly, even when the duration of the Q Comp implementation was considered, the Q Comp effect specific in charter schools was not significant. This result is different from the pattern in overall teacher retention rate seen in Table IV-5, where charter schools that implemented Q Comp for five years had significantly different retention rates from the other schools.

CHAPTER V: EFFECT ON STUDENT ACHIEVEMENT

This chapter reports the findings from the analyses of the student achievement model. The student achievement model used two kinds of test results to represent the level of student achievement of school: reading and mathematics of the Minnesota Comprehensive Assessment (MCA) for third graders. The results of analyses in this chapter provided answers to research question (3), the Q Comp effect on student achievement of schools, and (4c), the Q Comp effect on student achievement of schools that is distinctive in charter schools.

Students' Reading Achievement of Minnesota Schools

The reading achievement analysis includes 6,800 cases, which consist of 990 schools for eight years, from 2003 to 2010.[5] This study focused on the third graders' reading achievement so that the number of schools included in the analyses decreased significantly compared to the teacher retention model analyses. For the research period, the annual average of schools in the portion of students at or above the proficiency level on the MCA reading test fluctuated around 0.76, and after 2006 when it marked the top proficiency portion of 0.80, it decreased in 2010 to 0.75 (See Table V-1). After transforming the raw data to the school mean deviation scores, the means and standard deviations were reduced. The trend pattern, however, was the same.

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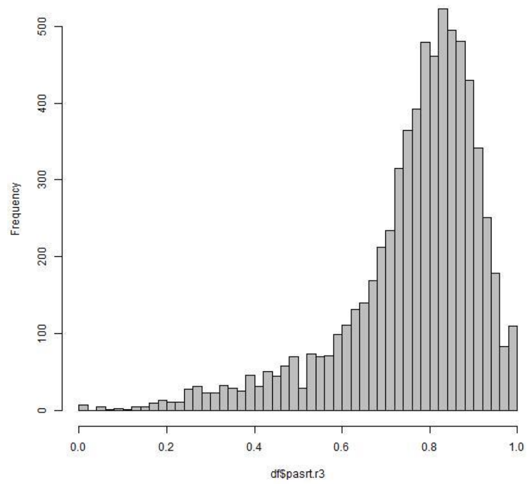
[5] Minnesota Comprehensive Assessment (MCA) test has been generally taken in April. Therefore, this study assumed that a MCA result in a given year reflects the students' learning from the fall of the previous year to spring of the given year. For example, 2003 MCA result reflected the students' learning for 2002-03 school year and 2010 MCA result did for 2009-10 school year.

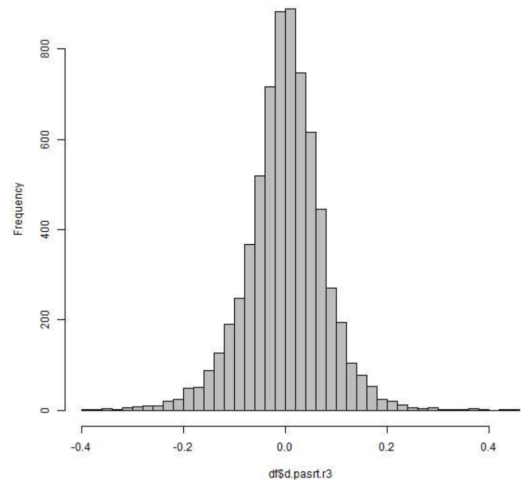
< Table V- 1 > Trend in Third Grade Reading Achievement of Minnesota Public Schools: 2003–2010

		(a) Student proficiency rates		(b) School-Mean-Deviation Student proficiency rates	
Year	N	Mean	SD	Mean	SD
2003	851	0.75	0.16	-0.01	0.08
2004	863	0.72	0.16	-0.04	0.08
2005	856	0.76	0.15	0.00	0.08
2006	836	0.80	0.14	0.03	0.07
2007	851	0.78	0.15	0.02	0.07
2008	853	0.77	0.17	0.01	0.07
2009	848	0.77	0.16	0.01	0.07
2010	842	0.75	0.17	-0.02	0.08

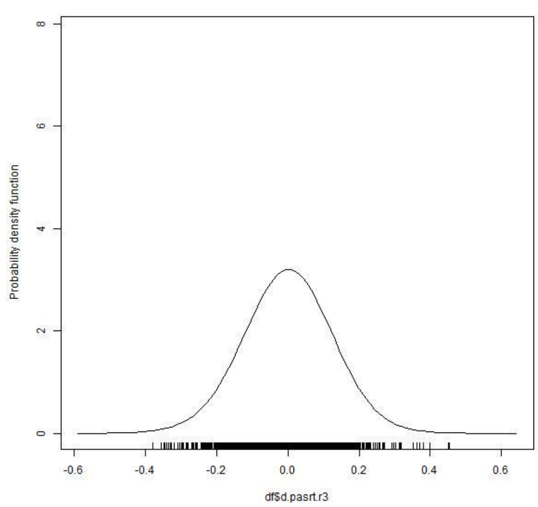
Even though the transformation into school mean deviation scores did not change the trend of annual means, the transformation influenced the distribution of variables and correlations among them. The distribution of the percentage of proficient students across cases was different from the normal distribution and was negatively skewed (See Figure VI-1 (a)). Changing the dependent variable into school-mean deviation scores made the distribution look like a normal distribution (See Figure V-1(b) and 2(c)). As seen in the quantile-quantile plot (Q-Q plot, see Figure V-1(d)), however, the distribution was heavy-tailed, as in the retention rate model. Because this analysis employed a large sample (N = 6,800), this violation was not very problematic (Gujarati & Sangeetha, 2008).



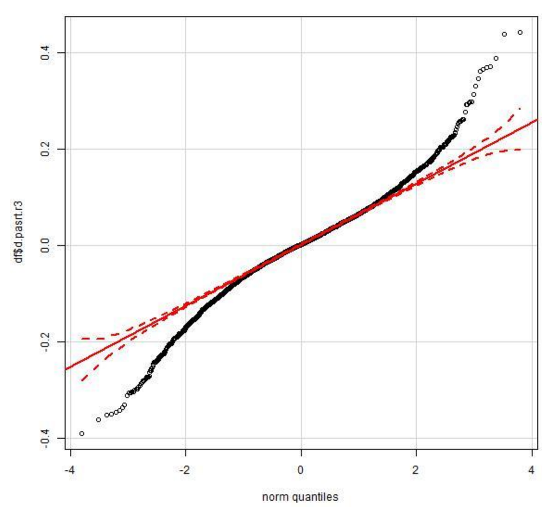
(a) Student Proficiency Rate in 3rd Grade Reading of MN Public Schools



(b) Student Proficiency Rate in 3rd Grade Reading of MN Public Schools (School-Mean-Deviated)



(c) Density Plot for Student Proficiency Rate in 3rd Grade Reading of MN Public Schools (School-Mean-Deviated)



(d) Q-Q Plot for Student Proficiency Rate in 3rd Grade Reading of MN Public Schools (School-Mean-Deviated)

Note. Figures were generated by the *sm package* (Bowman & Azzalini, 2014) and the *car package* (Fox et al., 2014) in the software R

[Figure V- 1] Distribution of Student Proficiency Rate in Third Grade Reading of Minnesota Public Schools

Correlation Analysis

This study performed a correlation analysis for the variables considered (See Table V-2(A)). The dependent variable, school's percentage of students who were at or above the proficiency level on the MCA reading test (student proficiency rate), was significantly correlated with the characteristics of school. That is, it was positively correlated with the student-teacher ratio (R= 0.05, $p < 0.01$) and negatively correlated with the percentage of minority students (R= -0.72, $p < 0.01$) and percentage of FRL students (R= -0.70, $p < 0.01$). As mentioned in Chapter 5, Minnesota schools' student-teacher ratio is negatively correlated with percentage of minority (not significantly, R= -0.02, $p > 0.10$) and FRL students (significantly, R= -0.12, $p < 0.01$). That could be a reason for the positive correlation between the student-teacher ratio and the student proficiency rates.

Minnesota charter schools had lower rates of student proficiency than traditional public schools (R= -0.25, $p < 0.01$), as is known in the literature. Minnesota charter schools also had a relatively higher percentage of minority and FRL students, which is consistent with the results of Chapter 4.

The Q Comp implementation was also positively correlated with the student proficiency rates (R= 0.03, $p < 0.01$). It was also associated with the percentage of minority students (R = 0.08, $p < 0.01$) and FRL students (R= -0.06, $p < 0.01$), which was significantly correlated with the dependent variable as well. Therefore, multiple regression analyses were needed to examine the Q Comp effect on the student proficiency rates after controlling for those variables.

The Q Comp implementation was correlated with school type ($R = 0.06$, $p < 0.01$). It could be interpreted that Minnesota charter schools were more likely to adopt Q Comp, which is consistent with the results of Chapter 4.

When this study considered the school fixed effects by transforming variables into school mean deviation scores, the correlation matrix changed (See Table V-2(B)). A decrease in the student-teacher ratio of a school was now correlated with an increase in the student proficiency rates, although it was a weak correlation ($R = -0.04$, $p < 0.01$). A decrease in the percentage of minority students showed a similar result ($R = -0.07$, $p < 0.01$). A decrease in the percentage of FRL students, however, was not associated with a change in the dependent variable. School type is a time-invariant variable so it was impossible to use in the correlation analysis with school mean deviation scores, and that correlation is marked as “NA.”

The implementation of Q Comp was still positively associated with the student proficiency rates after transforming the raw data into the school mean deviation score ($R = 0.04$, $p < 0.01$). It was also correlated with the student-teacher ratio ($R = 0.34$, $p < 0.01$) and percentage of minority students ($R = 0.26$, $p < 0.01$), which was also negatively associated with the dependent variable ($R = -0.04$, $p < 0.01$ and $R = -0.07$, $p < 0.01$, respectively). In the next section, this study examined the effect of Q Comp after controlling for the time-variant school characteristics.

< Table V- 2 > Correlation Matrix of Variables in Third Grade Reading Achievement Analysis

	Mean	SD	Student proficiency rates	S-T Ratio	Minority Student Rate	FRL Student Rate	School Type (Charter: 1)
	(A) Values before Transformation						
S-T Ratio	16.00	12.17	0.05**				
Minority Student Rate	0.26	0.28	-0.72**	-0.02			
FRL Student Rate	0.39	0.24	-0.70**	-0.12**	0.74**		
School Type^{+} (Charter)	0.06	0.24	-0.25**	0.05**	0.27**	0.21**	
Q Comp^{+}	0.12	0.32	0.03**	0.01	0.08**	-0.06**	0.06**
	(B) School Mean Deviation Values						
S-T Ratio	0.00	9.96	-0.04**				
Minority Student Rate	0.00	0.04	-0.07**	0.61**			
FRL Student Rate	0.00	0.05	0.01	-0.04**	-0.04**		
School Type^{++} (Charter)	NA	NA	NA	NA	NA	NA	
Q Comp	0.00	0.25	0.04**	0.34**	0.26**	-0.01	NA

* $p < .05$; ** $p < .01$

Note 1. This correlation matrix was developed by the *psych* package in *R* (Revelle, 2014).

Note 2. Because school type and Q Comp ($^{+}$ marked) were nominal variables, point-biserial correlation coefficients were calculated for them, which were calculated by *biserial.cor* function of the *ltm* package in *R* (Rizopoulos, 2013).

Note 3. School Type ($^{++}$ marked) was a time-invariant characteristic of school, so it was excluded from this correlation analysis.

Effect of Q Comp on Students' Reading Achievement

This study analyzed the students' reading achievement model with consideration of school and year fixed effects (Table V-3). Firstly, the student proficiency rates of schools was negatively and significantly correlated with the percentage of minority students (b = -0.1662, *s.e.* = 0.0403, t = -4.1273, $p < 0.01$) and the percentage of FRL students (b = -0.1640, *s.e.* = 0.0382, t = -4.2985, $p < 0.01$). That is, when the percentage of minority students increased by 10 percentage points, the student proficiency rates decreased by 1.662 percentage points. A 10 percentage points increase in the percentage of FRL students would be associated with a decrease of 1.640 percentage points in the student proficiency rates. These negative correlations are consistent with the previous studies that schools serving more disadvantaged students are more likely to show lower performance on student achievement (e.g., Roscigno, Tomaskovic-Devey, & Crowley, 2006).

Secondly, the Q Comp implementation was not significantly associated with student proficiency rates (b = 0.0085, *s.e.* = 0.0044, t = 1.9361, $p > .05$). When this study considered the length of time that schools implemented Q Comp, there was also no significant effect (Table V-3(B)).

< Table V- 3 > Result of Analysis on Student Achievement Model in Third Grade Reading

	(A) Q Comp - Binary		(B) Q Comp - Period	
	Estimate	S.E.	Estimate	S.E.
Year 2004	-0.0278	0.0001	0.0000	0.0001
Year 2005	0.0213 **	0.0403	-0.1662 **	0.0405
Year 2006	0.0534 **	0.0382	-0.1638 **	0.0382
Year 2007	0.0418 **	0.0038	-0.0278 **	0.0038
Year 2008	0.0385 **	0.0039	0.0213 **	0.0039
Year 2009	0.0355 **	0.0042	0.0534 **	0.0043
Year 2010	0.0189 **	0.0044	0.0417 **	0.0044
S-T Ratio	0.0000 **	0.0046	0.0385 **	0.0046
Minority Student Rate	-0.1662 **	0.0048	0.0358 **	0.0048
FRL Student Rate	-0.1640 **	0.0052	0.0188 **	0.0053
Q Comp	0.0085	0.0044		
1 Year Q Comp			0.0091	0.0053
2 Years Q Comp			0.0089	0.0059
3 Years Q Comp			0.0056	0.0065
4 Years Q Comp			0.0110	0.0073
5 Years Q Comp			0.0038	0.0175
R^2	0.0964		0.0965	
Adjusted R^2	0.0822		0.0822	
F Statistic	56.2373 **		41.2467 **	
N (Unbalanced Panel)	6800		6800	
n	990		990	
T	1-8		1-8	

* *p* < .05; ** *p*< .01

Note 1. Models (A) and (B) were analyzed by the *plm* function in the *plm* package of *R* (Croissant et al., 2013).

Note 2. In the Breusch-Godfrey/Wooldridge test on the result of the analysis, using the *pbgtest* function in the *plm package* of *R* (Croissant et al., 2013), result that there would present serial autocorrelation (χ^2(1) = 22.3165, p < 0.01 for the Model (A) and (χ^2(1) = 22.3998, p < 0.01) for the Model (B)). All standard errors were corrected by Newey-West method using the *coeftest* function with *vcovHC* and *method=”arellano”* in the *lmtest package* of *R*.

Based on these results, this study failed to find a significant effect of Q Comp on student achievement in reading. At least, even for schools with five years of implementation, this study did not find a Q Comp effect on reading achievement after accounting for the other variables.

Effect of Q Comp in Charter Schools

In the next step, this study examined the distinctive effect of Q Comp on student achievement in charter schools, research question 4(c). The interaction effect terms of time and school type as well as Q Comp implementation and school type were added in the previous model to the examination (See Table V-4).

< Table V- 4 > Result of Analysis on Student Achievement Model in Third Grade Reading: Focusing on Charter Schools

	(A) Q Comp - Binary		(B) Q Comp - Period	
	Estimate	S.E.	Estimate	S.E.
S-T Ratio	0.0000	0.0001	0.0000	0.0001
Minority Student Rate	-0.1582 **	0.0404	-0.1568 **	0.0405
FRL Student Rate	-0.1615 **	0.0374	-0.1624 **	0.0372
Year 2004	-0.0276 **	0.0038	-0.0276 **	0.0038
Year 2005	0.0209 **	0.0038	0.0209 **	0.0038
Year 2006	0.0518 **	0.0042	0.0518 **	0.0042
Year 2007	0.0386 **	0.0042	0.0384 **	0.0043
Year 2008	0.0366 **	0.0046	0.0367 **	0.0046
Year 2009	0.0330 **	0.0047	0.0336 **	0.0047
Year 2010	0.0166 **	0.0052	0.0163 **	0.0053
Year 2004:School Type (Charter)	0.0007	0.0288	0.0008	0.0288
Year 2005:School Type (Charter)	0.0171	0.0337	0.0172	0.0337
Year 2006:School Type (Charter)	0.0445	0.0351	0.0458	0.0352
Year 2007:School Type (Charter)	0.0712	0.0395	0.0746 .	0.0393
Year 2008:School Type (Charter)	0.0505	0.0369	0.0491	0.0371
Year 2009:School Type (Charter)	0.0569	0.0403	0.0522	0.0405
Year 2010:School Type (Charter)	0.0529	0.0415	0.0524	0.0440
Q Comp	0.0047	0.0043		
Q Comp: School Type	0.0350	0.0265		
1 Year Q Comp			0.0063	0.0053
2 Years Q Comp			0.0054	0.0056
3 Years Q Comp			-0.0006	0.0060
4 Years Q Comp			0.0069	0.0074
5 Years Q Comp			0.0082	0.0142
1 Year Q Comp: School Type			0.0214	0.0259
2 Years Q Comp: School Type			0.0344	0.0370
3 Years Q Comp: School Type			0.0762	0.0398
4 Years Q Comp: School Type			0.0492	0.0415
5 Years Q Comp: School Type			-0.0361	0.1095

(continued)

(continued)

R^2	0.1031	0.1041
Adjusted R^2	0.0878	0.0885
F Statistic	35.034**	24.8889**
N (Unbalanced Panel)	6800	6800
n	990	990
T	1-8	1-8

* $p < .05$; ** $p < .01$

Note 1. Models (A) and (B) were analyzed by the *plm* function in the *plm* package of *R* (Croissant et al., 2013).

Note 2. In the Breusch-Godfrey/Wooldridge test on the result of the analysis, using the *pbgtest* function in the *plm* package of *R* (Croissant et al., 2013), result that there would present serial autocorrelation ($\chi^2(1) = 22.3165$, p < 0.01 for the Model (A) and ($\chi^2(1) = 22.3998$, p < 0.01) for the Model (B)). All standard errors were corrected by Newey-West method using the *coeftest* function with *vcovHC* and *method="arellano"* in the *lmtest* package of *R*.

Note 3. Even though the all interaction terms between year and school type (Year 2004:School type ~ Year 2010: School Type) were not significant, when this study did not consider these interaction terms, the R^2 was decreased to 0.1004 and the two models were significantly different ($F(7, 5783) = 3.4275$, $p < 0.01$). Therefore, this study reported the presented model rather than the reduced model. Interestingly, in the reduced model, the coefficient of 3 Years Q Comp: School Type was significant, which is consistent with the math model, as described in the next section of this chapter.

Firstly, Minnesota schools had higher rates of student achievement in the latter years of the analysis compared to the 2002–03 or 2003–04 school years. For example, the student proficiency rate on the 2006 MCA reading test was 5.18 percentage points higher than in 2003 (b= 0.0518, *s.e*. = 0.0042, $t = 12.2956$, $p < 0.01$).

Secondly, in addition to the general improvement in student achievement over time, Minnesota charter schools did not show significant differences compared to the other schools. Even though all the coefficients were positive, they were not significant.

Third, Q Comp implementation was not significantly associated with student proficiency rates of schools (b= 0.0047, *s.e*. = 0.0043, $t = 1.1076$, $p > 0.10$). When the length of implementation was considered, this study did not find any evidence of a significant effect of Q Comp on student proficiency rates (e.g., in third implementation year, b= -0.0006, *s.e*. = 0.0060, $t = -0.1042$, $p > 0.10$).

Fourthly, as with traditional schools, charter schools did not enjoy a positive effect of Q Comp on their student proficiency rates (in Table V-4(A), b= 0.0350, *s.e*. = 0.0265, $t = 1.3207$, $p > 0.10$).

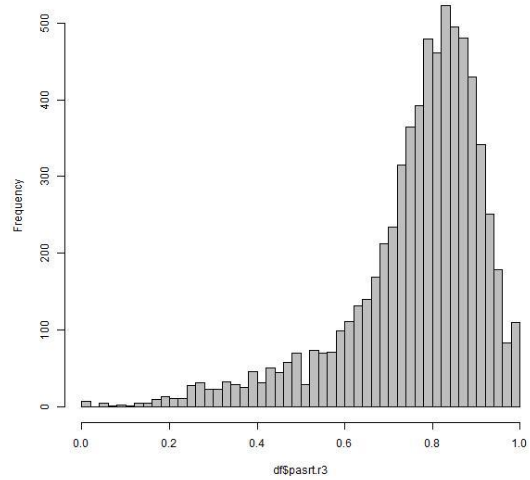
Students' Math Achievement of Minnesota Schools

The math achievement analysis includes 6,783 cases, which consist of 985 schools for eight years, from 2003 to 2010. For the research period, the annual average school rate in the portion of students at or above the proficiency level on the MCA math test fluctuated from 0.69 in 2004 to 0.81 in 2010 (See Table V-5(A)). After transforming the raw data to the school mean deviation scores, the means and standard deviations were reduced. The trend pattern, however, was the same (See Table V-5(B)).

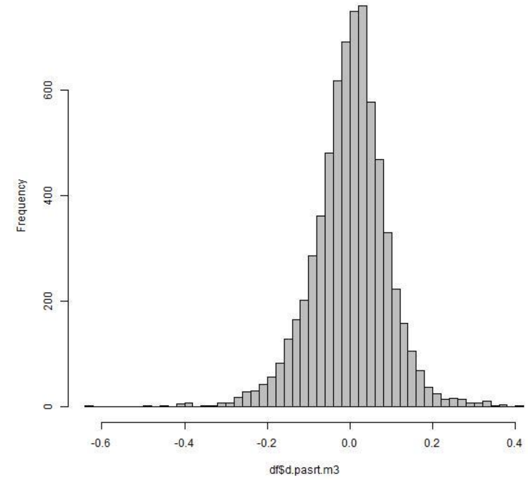
< Table V- 5 > Trend in Third Grade Math Achievement of Minnesota Public Schools: 2003–2010

		(a) Student Proficiency Rate		(b) School-Mean-Deviation Student Proficiency Rate	
Year	N	Mean	SD	Mean	SD
2003	856	0.73	0.16	-0.03	0.08
2004	862	0.69	0.17	-0.07	0.09
2005	857	0.75	0.16	-0.01	0.08
2006	842	0.76	0.16	0.00	0.08
2007	845	0.77	0.15	0.00	0.08
2008	846	0.79	0.15	0.03	0.08
2009	838	0.80	0.15	0.03	0.08
2010	837	0.81	0.15	0.04	0.08

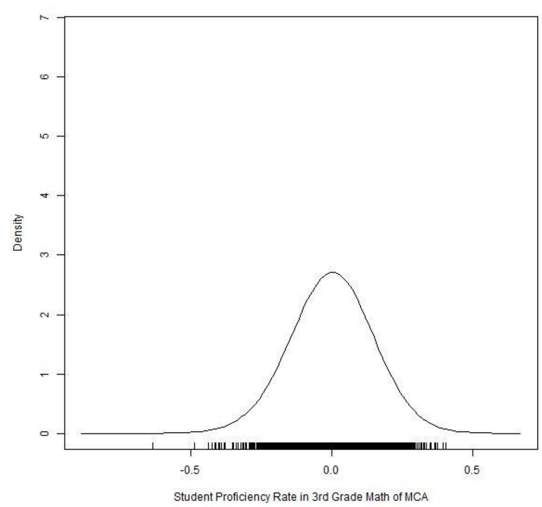
The distribution of the student proficiency rate across cases was different from the normal distribution and was negatively skewed (See Figure VI-1 (a)). Changing the dependent variable into school-mean deviation scores made the distribution look like a normal distribution (See Figure VI-1(b) and 2(c)). As seen in the quantile-quantile plot (Q-Q plot, see Figure V-1(d)), however, the distribution was heavy-tailed, as it was in the retention rate model and in the reading achievement model. In spite of the violation of the normality assumption, the large sample size of this analysis (N = 6,774) mitigates this threat to validity (Gujarati & Sangeetha, 2008).



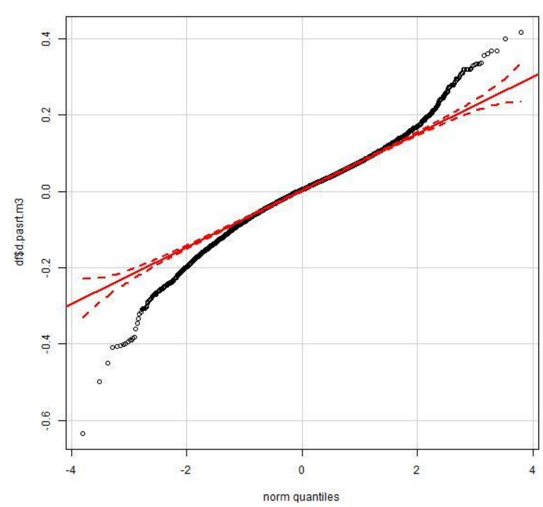
(a) Student Proficiency Rate in 3rd Grade Math of MN Public Schools



(b) Student Proficiency Rate in 3rd Grade Math of MN Public Schools (School-Mean-Deviated)



(c) Density Plot for Student Proficiency Rate in 3rd Grade Math of MN Public Schools (School-Mean-Deviated)



(d) Q-Q Plot for Student Proficiency Rate in 3rd Grade Math of MN Public Schools (School-Mean-Deviated)

Note. Figures were generated by the *sm package* (Bowman & Azzalini, 2014) and the *car package* (Fox et al., 2014) in the software R

[Figure V- 2] Distribution of Student Proficiency Rate in Third Grade Math of Minnesota Public Schools

Correlation Analysis

Correlations among variables (see Table V-6) look similar to the results of the reading achievement analysis described in Table V-2. The Q Comp implementation was also positively correlated with the student proficiency rates ($R = 0.11$, $p < 0.01$). While it was weakly correlated, the association was larger than the correlation of the Q Comp implementation and the student proficiency rates in reading.

Q Comp implementation was correlated with school type ($R = 0.05$, $p < 0.01$). It could be interpreted that Minnesota charter schools were more likely to adopt Q Comp, which is consistent with the results of the reading analysis.

When this study considered the school fixed effects by transforming variables into school mean deviation scores, the implementation of Q Comp was still positively associated with the student proficiency rates ($R = 0.15$, $p < 0.01$). It was also correlated with the student-teacher ratio ($R = 0.34$, $p < 0.01$) and percentage of minority students ($R = 0.26$, $p < 0.01$).

< Table V- 6 > Correlation Matrix of Variables in Third Grade Math Achievement Analysis

	Mean	SD	Student proficiency rates	S-T Ratio	Minority Student Rate	FRL Student Rate	School Type (Charter: 1)
			(A) Values before Transformation				
S-T Ratio	16.01	12.19	0.03*				
Minority Student Rate	0.25	0.28	-0.62**	-0.01			
FRL Student Rate	0.39	0.24	-0.63**	-0.12**	0.74**		
School Type+ (Charter)	0.06	0.24	-0.26**	0.05**	0.25**	0.19**	
Q Comp+	0.12	0.32	0.11**	0.01	0.07**	-0.06**	0.05**
			(B) School Mean Deviation Values				
S-T Ratio	0.00	9.95	0.00				
Minority Student Rate	0.00	0.04	0.13**	-0.04**			
FRL Student Rate	0.00	0.05	0.09**	0.60**	-0.04**		
School Type++ (Charter)	NA	NA	NA	NA	NA	NA	
Q Comp	0.00	0.24	0.15**	0.34**	0.26**	-0.01	NA

* $p < .05$; ** $p < .01$

Note 1. This correlation matrix was developed by the *psych* package in *R* (Revelle, 2014).

Note 2. Because school type and Q Comp (+ marked) were nominal variables, point-biserial correlation coefficients were calculated for them, which were calculated by *biserial.cor* function of the *ltm* package in R (Rizopoulos, 2013).

Note 3. School Type (++ marked) was a time-invariant characteristic of school so it was excluded from this correlation analysis.

Effect of Q Comp on Students' Math Achievement

This study analyzed the students' math achievement model with consideration of school and year fixed effects (Table V-7). The result looks similar to the reading achievement analysis. Firstly, the student mathematics proficiency rate of schools was negatively and significantly associated with the percentage of FRL students (b = -0.1954, *s.e*. = 0.0290, $t = -6.7419$, $p < 0.01$). Math proficiency, however, was not significantly correlated with the percentage of minority students (b = -0.0636, *s.e*. = 0.0359, $t = -1.7716$, $p > 0.05$), which is different from the result of the reading achievement analysis.

Secondly, the Q Comp implementation was not associated with student proficiency rates (b = 0.0072, *s.e*. = 0.0049, $t = 1.4739$, $p > .10$). When this study considered the length of time that Q Comp was implemented, there was also no significant effect (Table V-3(B)). The result is similar to the results of the reading achievement analysis.

< Table V- 7 > Result of Analysis on Student Achievement Model in Third Grade Mathematics

	(A) Q Comp - Binary		(B) Q Comp - Period	
	Estimate	S.E.	Estimate	S.E.
S-T Ratio	0.0000	0.0001	0.0000	0.0001
Minority Student Rate	-0.0636	0.0359	-0.0610	0.0360
FRL Student Rate	-0.1954 **	0.0290	-0.1955 **	0.0290
Year 2004	-0.0377 **	0.0043	-0.0377 **	0.0043
Year 2005	0.0301 **	0.0044	0.0300 **	0.0044
Year 2006	0.0396 **	0.0045	0.0395 **	0.0045
Year 2007	0.0454 **	0.0046	0.0451 **	0.0047
Year 2008	0.0736 **	0.0047	0.0733 **	0.0048
Year 2009	0.0827 **	0.0049	0.0823 **	0.0049
Year 2010	0.0979 **	0.0051	0.0989 **	0.0052
Q Comp	0.0072	0.0049		
1 Year Q Comp			0.0085	0.0069
2 Years Q Comp			0.0074	0.0070
3 Years Q Comp			0.0111	0.0079
4 Years Q Comp			-0.0007	0.0091
5 Years Q Comp			-0.0029	0.0198
R^2	0.1730		0.1733	
Adjusted R^2	0.1476		0.1477	
F Statistic	109.9040 **		80.6666 **	
N (Unbalanced Panel)	6774		6774	
n	985		985	
T	1-8		1-8	

* $p < .05$; ** $p < .01$

Note 1. Models (A) and (B) were analyzed by the *plm* function in the *plm* package of *R* (Croissant et al., 2013).

Note 2. In the Breusch-Godfrey/Wooldridge test on the result of the analysis, using the *pbgtest* function in the *plm* package of *R* (Croissant et al., 2013), result that there would not present serial autocorrelation ($\chi^2(1) = 0.4811$, p > 0.10 for the Model (A) and ($\chi^2(1) = 0.5142$, p < 0.01) for the Model (B)). All standard errors were not corrected by Newey-West method.

Effect of Q Comp in Charter Schools

In the next step, this study considered the distinctive effect of Q Comp on students' math achievement in charter schools, research question 4(c). The interaction effect terms of time and school type as well as Q Comp implementation and school type were added to the examination in the previous model (See Table V-8).

Firstly, in the later years of analysis, Minnesota schools had higher rates of student proficiency in 3rd grade math achievement compared to 2002–03, except for the 2003–04 school year. On average, other things being equal, Minnesota charter schools had higher math proficiency rates in 2007, 2008, 2009, and 2010 than charter schools in 2003; that is b= 0.0637, *s.e.* = 0.0217, $t = 2.9378$, $p < 0.01$ in 2006-07; b= 0.0687, *s.e.* = 0.0215, $t = 3.1910$, $p < 0.01$ in 2007-08; b= 0.0886, *s.e.* = 0.0220, $t = 4.0286$, $p < 0.01$ in 2008-09; and b= 0.0780, *s.e.* = 0.0222, $t = 3.5164$, $p < 0.01$ in 2009-10.

Second, the Q Comp implementation was not significantly associated with the student proficiency rates of traditional schools (in Table V-8(A), b= 0.0016, *s.e.* = 0.0051, $t = 0.311$, $p > 0.10$). When the length of implementation was considered, this study did not find any evidence of a significant effect of Q Comp on student proficiency rates (e.g., for schools with three years of Q Comp implementation, b= 0.0025, *s.e.* = 0.0081, $t = 0.3093$, $p > 0.10$ in Table V-8(B)). This result is consistent with the results from the reading achievement analysis.

< Table V- 8 > Result of Analysis on Student Achievement Model in Third Grade Mathematics: Focusing on Charter Schools

	(A) Q Comp - Binary		(B) Q Comp - Period	
	Estimate	S.E.	Estimate	S.E.
Year 2004	-0.0365**	0.0043	-0.0366**	0.0043
Year 2005	0.0304**	0.0044	0.0303**	0.0044
Year 2006	0.0385**	0.0045	0.0382**	0.0045
Year 2007	0.0427**	0.0047	0.0422**	0.0047
Year 2008	0.0708**	0.0048	0.0704**	0.0049
Year 2009	0.0783**	0.0049	0.0782**	0.0050
Year 2010	0.0939**	0.0052	0.0947**	0.0053
S-T Ratio	0.0000	0.0001	0.0000	0.0001
Minority Student Rate	-0.0457	0.0358	-0.0410	0.0360
FRL Student Rate	-0.1925**	0.0289	-0.1937**	0.0289
Year 2004:School Type (Charter)	-0.0247	0.0214	-0.0245	0.0214
Year 2005:School Type (Charter)	0.0001	0.0212	0.0004	0.0212
Year 2006:School Type (Charter)	0.0360	0.0213	0.0373	0.0213
Year 2007:School Type (Charter)	0.0637**	0.0217	0.0674**	0.0219
Year 2008:School Type (Charter)	0.0687**	0.0215	0.0675**	0.0216
Year 2009:School Type (Charter)	0.0886***	0.0220	0.0845**	0.0222
Year 2010:School Type (Charter)	0.0780***	0.0222	0.0814**	0.0229
Q Comp (Q Comp)	0.0016	0.0051		
Q Comp: School Type	0.0493*	0.0197		
1 Year Q Comp			0.0041	0.0071
2 Years Q Comp			0.0019	0.0073
3 Years Q Comp			0.0025	0.0081
4 Years Q Comp			-0.0060	0.0094
5 Years Q Comp			-0.0010	0.0210
1 Year Q Comp: School Type			0.0373	0.0250
2 Years Q Comp: School Type			0.0440	0.0259
3 Years Q Comp: School Type			0.1030**	0.0321
4 Years Q Comp: School Type			0.0442	0.0355
5 Years Q Comp: School Type			-0.0368	0.0623
R^2	0.1850		0.1862	
Adjusted R^2	0.1576		0.1584	
F Statistic	68.9156**		48.8319**	
N (Unbalanced Panel)	6774		6774	
n	985		985	
T	1-8		1-8	

* $p < .05$; ** $p < .01$

Note 1. Models (A) and (B) were analyzed by the *plm* function in the *plm* package of *R* (Croissant et al., 2013).

Note 2. In the Breusch-Godfrey/Wooldridge test on the result of the analysis, using the *pbgtest* function in the *plm* package of *R* (Croissant et al., 2013), result that there would not present serial autocorrelation ($\chi^2(1) = 0.1932$, p > 0.10 for the Model (A) and ($\chi^2(1) = 0.2$, p < 0.01) for the Model (B)). All standard errors were not corrected by Newey-West method.

Thirdly, in contrast to the other schools, on average, charter schools that implemented Q Comp enjoyed a positive effect of Q Comp on their student proficiency rates (in Table V-8(A), b= 0.0493, *s.e.* = 0.0197, $t = 2.4999$, $p < 0.05$). Charter schools that implemented Q Comp for three years had proficiency rates that were 10.3 percentage points higher than other schools in the (in Table V-8(B), b= 0.1030, *s.e.* = 0.0321, $t = 3.2123$, $p < 0.01$). This finding is different from the results of the reading analysis where the difference between charter schools that implemented Q Comp for three years and the other schools was not significant (b= 0.0762, *s.e.* = 0.0398, $t = 1.9141$, $p = 0.0557 > 0.05$).

Fourthly, the charter school specific effect of Q Comp in schools with 3 years of Q Comp implementation was not found in schools with different years of implementation of Q Comp. The coefficients were not significant for different years of implementation; note also that the size of the coefficient decreased as the duration of implementation increased (b= 0.0442, *s.e*. = 0.0355, $t = 1.2453$, $p > 0.10$ in schools with 4 years of Q Comp and b= -0.0368, *s.e*. = 0.0623, $t = -0.5913$, $p > 0.10$ in schools with 5 years of Q Comp).

CHAPTER VI: CONCLUSION AND DISCUSSION

Conclusion

This study analyzed the association of alternative teacher compensation programs with teacher retention rates and student achievement in the case of the Minnesota Quality Compensation program. The analyses provided important answers for the research questions raised. The results are summarized in the following paragraphs and a fuller discussion that includes policy implications is discussed in subsequent sections.

First, the results of the analysis indicate that alternative teacher compensation programs had effects on schools' overall retention rates of teachers. The analysis indicates, however, that it took at least five years for significant effects to appear. Consistent with the previous studies mentioned in Table II-1, the effect of Q Comp was not significant even after four years of implementation. This study found a positive effect of Q Comp in schools with 5 years of implementation, which previous studies had not examined. Thus, policymakers and educators would have to be prepared to give ACPs sufficient time to work before making summative decisions on their effectiveness.

Second, alternative teacher compensation programs had an effect on schools' retention rates of experienced teachers. It also took at least five years for this effect to be visible, however.

Third, alternative teacher compensation programs had no significant effect on overall student achievement as measured by third-grade proficiency rates in reading and mathematics. However, there were significant findings for charter schools; these findings are described below. Overall, even after 5 years of implementing Q Comp, there was no considerable difference in student proficiency rates. While the student body changed over that time, the rhetoric associated with the policy suggested that it should have a systematic positive effect. The findings do not support that assumption.

Fourth, aside from the general effect, charter schools that implemented Q Comp typically had lower overall teacher retention rates. These significantly lower rates were apparent in schools that had implemented Q Comp for 5 years.

Fifth, while ACPs were associated with lower overall teacher retention rates in charter schools, there was no distinctive effect for charter schools of alternative teacher compensation programs on schools' retention rates of experienced teachers.

Sixth, charter schools that implemented Q Comp had significantly different rates of proficiency from other schools; traditional schools that implemented Q Comp did not have significantly different proficiency rates from other schools. The charter-specific effect peaked in schools with 3 years of implementation in reading as well as in math, but was statistically significant only for math.

Discussion

Reviewing the previous studies on ACPs, this study saw the need to examine alternate compensation programs that have been in place over a relatively long period. In addition, this study hypothesized the possibility of ACPs' distinctive effect across school types. The findings of this study showed the significance of considering long-term effects and school-type-specific effects. On the other hand, the findings of this study raised additional questions, which I discuss below.

Time is Needed for ACPs to Bear Fruit

Most reforms need some amount of time to realize their effect (Fullan, 2007). This is true for ACPs. The sizes of coefficients, regardless of the significance, were large in schools with 1 year of implementation and then typically decreased for schools with 2, 3, or 4 years of implementation. However, in schools with 5 years of implementation the coefficient was positive and significant. Recall the Texas GEEG study (Springer, Lewis, Podgursky, Ehlert, Taylor, et al., 2009) that found a significant effect only in the first implementation year. Considering the results of the Texas study and this study, the first year would be special in the short-term implementation even though it was not significant in this study. There may be higher expectations for the new program in the first implementation year. After the initial year, however, the novelty would disappear and struggles to develop "a shared meaning of the new program in school" (Fullan, 2007) would begin. As a result, it would be difficult to discover significant effects of ACPs in the early years (years 2-4) of implementation once the novelty wore off from the initial year. These conclusions are consistent with the results of this study and previous studies. After developing the shared meaning, however, schools could reap the benefit of the new program, and this study found some significant effect of Q Comp after five years of implementation.

Regarding teacher retention rates, there was no significant effect of Q Comp except for schools with 5 years of implementation. Therefore, if this study used samples with shorter terms of ACP implementation, it might have failed to find significant effects. As with many other reform efforts (e.g., Sass, 2006, found that new charter schools take five years of operation to catch up or exceed traditional schools in student achievement), it seems that ACPs also needed at least five years of implementation to realize the effect of change. However, we are unable to tell if this effect would be sustained in schools with six or more years of implementation.

This study did not find evidence of ACPs' effect on student achievement, which may be an indication that it might take more time for the effect of ACPs on student achievement to be realized. According to a theoretical argument, ACPs' effect on teacher retention, especially on the retention of teachers with certain characteristics associated with student achievement, could strengthen the teaching force of schools. This enhancement could eventually lead to an improvement in student achievement (Lazear, 2003). Based on this logic, the findings of this study regarding teacher retention could be a signal of future improvements in student achievement for the schools included in this analysis.

Sustainability of the Effect

This study found evidence that at least five years would be needed to see the effect of ACPs on teacher retention rates. However, there was no answer for the question of sustainability, which is a limitation of this study. The question of sustainability is particularly relevant for the findings regarding student achievement; the effect of Q Comp on students' math achievement appeared in schools with 3 years of implementation but was not found in schools with more years of implementation. These findings led to questions on the sustainability of the ACPs, which is an important issue for policymakers to consider when making decisions as to whether the program will be continued or stopped.

In addition, an important corollary would be what characteristics of schools are associated with the sustainability of ACPs. This study did not focus on this question. Considering the low values of R-squared for the analyses (from 0.0124 to 0.0269 in the retention rate model and from 0.0964 to 0.1862 in the student achievement model), there are likely more variables associated with variations in the dependent variables that were not included in this study. More studies are needed to determine which school characteristics are associated with the dependent variables and which variables mediated the association between the dependent variables and ACPs. For example, leadership succession would be a good candidate for pursuing that question (Hargreaves & Goodson, 2006). Given the strong relationships between leadership and teacher retention and between leadership and student achievement (Boyd et al., 2011; Louis, Dretzke, & Wahlstrom, 2010), leadership succession would mediate the association between teacher retention and ACPs and between student achievement and ACPs, which could be a future avenue of research.

Dilemma in Charter Schools: Relationship Between Teacher Retention Rate and Student Achievement

Even though many significant effects of Q Comp were found in this study, the two effects on teacher retention rate and student achievement do not seem to be related with each other. In other words, Q Comp had a positive and significant association with teacher retention rates in traditional schools, but this association was not significant for student achievement in traditional schools. Moreover, in charter schools, Q Comp showed a relatively negative effect on overall teacher retention rates but a relatively positive effect on students' math achievement. The positive and negative effects would put charter school policymakers into a dilemma regarding Q Comp implementation: Do they adopt Q Comp for student achievement at the risk of decreasing teacher retention rate? Considering the relationship between decrease in teacher retention rate and lower student achievement (Carruthers, 2012; Stuit & Smith, 2012), can we say that the risk of decreasing teacher retention rate in Q Comp charter schools would not result in a decrease in student achievement in the near future?

As a way to address this question, let's remember that the retention rate of teachers with certain characteristics associated with student achievement would be more important than the retention rate of overall teachers in terms of student achievement (Lazear, 2003). This leads us to a result of this study that the retention rate of experienced teachers was not decreased in the midst of the decrease in the retention rate of teachers overall in charter schools with 5 years of Q Comp implementation. That the retention rate of experienced teachers in charter schools with Q Comp was not decreased could be interpreted as an indication that the ability of charter schools with Q Comp to retain teachers with certain characteristics associated with higher student achievement was not decreased. If the charter schools with Q Comp could fill the vacant positions with teachers who had certain characteristics associated with higher student achievement, the teaching force of the charter schools would be improved, and the improved teaching force would be positive for improving student achievement in future. Therefore, to answer the dilemma presented above, an additional investigation on teacher recruitment of charter schools with Q Comp will be needed in a future study.

Teacher Retention in Charter School

This study found that Minnesota charter schools have seen improved rates of teacher retention from 2003 to 2010 compared to traditional public schools. One possible explanation for this pattern could be the relationship of the increase in teacher retention rates in charter schools with the highly qualified teacher initiative under the No Child Left Behind Act (NCLB). Moreover, this study defined the teacher retention rate by focusing on teachers who taught academic core subjects, which was the target group of the policy. That is, the NCLB required schools to assign highly qualified teachers, mostly defined by their major in college and formal certification (U.S. Department of Education, 2004), to academic core subjects. The act made it more important for schools to retain their highly qualified teachers. Charter schools that have been reported to have a relatively lower retention rate of teachers (Carruthers, 2012; Cowen & Winters, 2012; Stuit & Smith, 2012) might have exerted more effort to retain their highly qualified teachers in the core subjects to meet the requirement of the law. As a result, charter schools in Minnesota would show improvement in their teacher retention rate during the research period as a result of factors other than implementation of ACPs. If this were true, the NCLB policy would be effective in improving the teacher retention rate in charter schools. Even though this issue was not a primary focus of this study, it would be helpful if more studies examined the effect of NCLB policy on teacher retention rates.

Limitations of This Study

Despite attempting to produce unbiased estimates as much as possible, this study still involved a possibility of biased estimation on the Q Comp coefficient because it included non-Q Comp schools, as stated in Chapter III. This study provides more information on the possibility of biased estimation in the Appendix. Even though inclusion of non-Q Comp schools made this study control for year fixed effects on dependent variables, this inclusion also presented the possibility of biased estimation, which should be considered in the interpretation of results in this study.

Another limitation of this study is that it focused on teacher retention rate and student achievement as outcomes of ACPs, which is a narrow view of the effectiveness of ACPs. Even though teacher retention rate and student achievement would be important outcomes of ACPs, more comprehensive understanding of ACPs on various school outcomes will be needed to evaluate and improve this new program. For example, a qualitative study reported that Q Comp might improve communication between teachers and administrators as well as increase teachers' workloads (Wahlstrom et al., 2006). The same study also found that students in schools with Q Comp felt unwanted pressure that "they could feel for having an effect upon their teachers' salaries" (Wahlstrom et al., 2006, p. 14). Moreover, considering concerns that emphasizing extrinsic motivation could decrease intrinsic motivation, which would affect long-term performance of an organization (Osterloh & Frey, 2002), intrinsic motivation of teachers under ACPs should be given attention. When we consider studies on various effects of ACPs together with this study, we can develop a comprehensive understanding of ACPs.

It is also a limitation of this study not to consider variation in design of ACPs. Because ACPs are generally permitted to design their own programs for schools within some requirements, implementation of ACPs would vary across characteristics of design (Minnesota Office of the Legislative Auditor, 2009; Wahlstrom et al., 2006). Because of data limitations and an interest in the average Q Comp effect, this study did not consider differences in design. The different design characteristics of ACPs, however, are an important issue to investigate in future studies.

Finally, it should be stated that the models used in this study showed very low R^2, which suggests that this model would explain only a little of the within-school variation of teacher retention rate and student achievement of schools. The low R^2 could be related to considerations of school fixed effects. Let's remember the result of the correlation analyses among variables before and after transforming mean-deviation scores. Before transformation to mean-deviation scores—that is, before the consideration of school fixed effects—correlations of teacher retention with school characteristics including percentage of minority students, percentage of FRL students, student–teacher ratio, and the number of students enrolled were significant. Those characteristics can show well the difference in working conditions related with teacher retention within and between schools. After consideration of school fixed effects, however, the correlations became weaker or insignificant. After removing between-school variance and focusing on within-school variance, these characteristics became limited to represent the differences in working conditions. This implies that changes of characteristics in student groups of schools, student-teacher ratio, and number of students would only capture a limited number of characteristics of schools associated with changes in teacher retention rates or student achievement. In the future, it is important to include variables to explain within-school changes of teacher retention rates or student achievement. As mentioned above, including characteristics on ACP design would be a promising approach to explain within-school changes of ACP schools.

Contributions of This Study

Even though it has limitations, this study contributes to the discourse and understanding of alternative compensation programs by examining Minnesota Q Comp. Firstly, by using longitudinal data, this study investigated relatively long-term program effects. This research period includes 5 years of implementation of ACPs, which made it possible to find a long-term effect of ACPs. Findings on the effect of Q Comp on teacher retention rate for schools that implemented this program for 5 years proved the usefulness of a long-term investigation.

Secondly, this study found that the effect of ACPs could differ by school type. Even though this study did not find evidence on continuing effects of ACPs in charter schools, there were significant effects of Q Comp on students' math achievement compared to traditional schools. This implies that ACPs as a voluntary program might be more attractive for charter schools, not only for receiving more resources but also for improving student achievement. If it is possible to sustain Q Comp effects in charter schools, ACPs could be a useful way to improve these organizations.

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Appendix. Discussion on Biasedness of Q Comp Effects Estimation

This study compared school cases between pre- and post-Q Comp implementation to estimate the difference related with Q Comp implementation. This study also considered differences related with year by including schools which had never experienced Q Comp. The inclusion of those schools, however, would make Q Comp effects estimation biased. This issue was considered with examples in Table A1.

In the left panels of the Table A1, this study assumed the real Q Comp effect was 12. A school which had never implemented Q Comp (Non-QC) was included in the second column of the panel and the school had a value of 0 for the dependent variable for the four observed years. The other school which experienced Q Comp in 2005-06 and 2006-07 school year (QC) was considered in the third column of the panel. It basically showed a value of 2 for the dependent variable, different from the Non-QC school. After Q Comp implementation in 2005-06 and 2006-07, the QC school had 14 as the value of the dependent variable because of the assumed Q Comp effect. Those were presented in Panel 1a in Table A1.

Panel 1b in Table A1 showed the result of including school fixed effects by mean-centering. Because the mean of Non-QC school was zero, the values of Non-QC school were not changed. Because the mean of the QC school was 8, however, the values of the QC school were decreased by 8.

Panel 1c in Table A1 showed the result of mean comparison between *with* and *without* Q Comp implementation cases, which is the approach used in this study. The mean of cases with Q Comp (two white colored columns in Panel 1b) was 6. On the other hand, the mean of cases without Q Comp (six gray colored columns in Panel 1b) was -2. Therefore, the estimated Q Comp effects would be 8 (6 - (-2) = 8), which was biased downwardly, that is, underestimated by 4 (12 - 8 = 4), compared to the assumed Q Comp effect of 12.

< Table A1 > Comparison Estimated Effects between *with* and *without* Non Q Comp schools

Panel 1a		
	Non-QC	QC
2003-04	0	2
2004-05	0	2
2005-06	0	14
2006-07	0	14
mean	0	8

Panel 2a		
	Non-QC	QC
2003-04	0	0
2004-05	0	0
2005-06	0	24
2006-07	0	24
mean	0	12

Panel 1b		
	Mean-Centered	
	Non-QC	QC
2003-04	0	**-6**
2004-05	0	**-6**
2005-06	0	6
2006-07	0	6

Panel 2b		
	Mean-Centered	
	Non-QC	QC
2003-04	0	**-12**
2004-05	0	**-12**
2005-06	0	12
2006-07	0	12

Panel 1c (with Non-QC schools)		
mean|QC=0	-2	
mean|QC=1		6
δ=8		
Y= -2 + 8(QC)		

Panel 2c (with Non-QC schools)		
mean|QC=0	-4	
mean|QC=1		12
δ=16		
Y= -4 + 16(QC)		

Panel 1d (without Non-QC schools)		
mean|QC=0		**-6**
mean|QC=1		6
δ=12		

Panel 2d (without Non-QC schools)		
mean|QC=0		**-12**
mean|QC=1		12
δ=24		

Source. S. S. Yeh (personal communication, December 9, 2014).

Panel 1d in Table A1 described the result of comparison without non-Q Comp schools. . The mean of cases with Q Comp (two white colored columns in Panel 1b) was still 6. On the other hand, the mean of cases without Q Comp (two bold typed columns in Panel 1b) was -6, which was different from the Panel 1c. As a result, the estimated Q Comp effects would be 12 (6 - (-6) = 12), which was unbiased, compared to the assumed Q Comp effect of 12.

Let’s consider one more example to see the relationship between the real effect size and the degree of biasedness. In the right panels of the Table A1, the real Q Comp effect was assumed to be 24, which is bigger than in the left panels. School fixed effects for both Non-QC and QC schools were zero. After the same processing with the left panels, this study estimated Q Comp effects to be 16 if we include Non-QC schools and 24 if we exclude Non-QC schools. The method includingNon-QC schools again produced a biased estimate of Q Comp effect by 8 (24 – 16 = 8) and the degree of biasedness was bigger than in the left panels.

Those examples lead to concerns that the estimated Q Comp effects would be biased in this study which included Non-QC schools. In spite of the concern, this study included Non-QC schools for three reasons. Firstly, as described in Chapter 3 of this study, the inclusion of Non-QC schools was necessary to consider for differences related with time. Secondly, the way of including Non-treatment objectives has been widely used in program effect evaluation studies (e.g., Bifulco, Cobb, & Bell, 2009). Thirdly, the statistical analysis seems to be processed in a way to exclude the possibility of biasedness in a simulation. To check the actual result of analysis in statistical software, I developed a simple data set based on the left panel of the Table A1 as below.

< Table A2 > Data for Simulating Q Comp Effect Estimation *with* Non Q Comp schools

schid	dv	qcomp	year
1	0	0	1
1	0	0	2
1	0	0	3
1	0	0	4
4	2	0	1
4	2	0	2
4	14	1	3
4	14	1	4

Source. Author developed based on the example of S. Yeh (personal communication, December 9, 2014), seen in the Table A1.

With the data, this study did statistical analysis with the software R as described in Figure A1 with *R* syntax. The result showed that the statistical analysis produced unbiased estimates for the coefficient of Q Comp, 12 (see in the Step 3 in Figure A1). This result can be interpreted that the actual process of fixed effect model to estimate the coefficient would be different with the process shown in Table A1. This study, however, did not fully understand the process so it cannot exclude the possibility of the biased estimates described above.

Step 1: Read data as a name of "test":

R syntax: test <- read.csv(file="qcomp/dissertation/defense/test2.csv",header=TRUE)

Step 2: Analyze data with consideration of school fixed effects by *plm* package

R syntax: library(plm)

t1 <- plm(dv ~ 1+factor(qcomp),index=c("schid"),model="within",data=test)

Step 3: Print the result

R syntax: summary(t1)

```
Oneway (individual) effect Within Model

Call:
plm(formula = dv ~ 1 + factor(qcomp), data = test, model = "within", index = c("schid"))

Balanced Panel: n=2, T=4, N=8

Residuals :
  Min. 1st Qu.  Median 3rd Qu.    Max.
     0       0       0       0       0

Coefficients :
                Estimate Std. Error  t-value  Pr(>|t|)
factor(qcomp)1        12          0      Inf < 2.2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares:    144
Residual Sum of Squares: 0
R-Squared      :  1
    Adj. R-Squared :  0.625
F-statistic: Inf on 1 and 5 DF, p-value: < 2.22e-16
```

[Figure A1] Process of Data Analysis for Simulating Q Comp Effect Estimation in the Software *R*

In addition to the result of simulation, the inclusion of the non-Q Comp schools was necessary to consider changes in teacher retention rates or student proficiency rate related with time. The dependent variables could be changed by year. An example is changes in student proficiency rate associated with version change of the tests as discussed in Chapter III. Changes in teacher retention rate associated with economic conditions would be another example. Most of all, all schools in practice, regardless of whether or not they formally accepted Q Comp, tried to improve teacher retention rate and student achievement, which would lead annual changes. In a practical sense, excluding these schools from the analysis would accord more of the change to formal implementation of the Q-Comp program than would be warranted. Therefore, these annual differences would need to be addressed in the analysis by including non-Q Comp schools and controlling for year fixed effects even though the possibility of unbiased estimation from the inclusion of non-Q comp schools.