# The Labor Market for Teachers Under Different Pay Schemes

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**Abstract**

Compensation of most US public school teachers is rigid and solely based on seniority. This paper studies the effects of a reform that gave school districts in Wisconsin full autonomy to redesign teacher pay schemes. Following the reform some districts switched to flexible compensation. Using the expiration of pre-existing collective-bargaining agreements as a source of exogenous variation in the timing of changes in pay, I show that the introduction of flexible pay raised salaries of high-quality teachers, increased teacher quality (due to the arrival of high-quality teachers from other districts and increased effort), and improved student achievement.

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Teachers are a key input for the production of student achievement (Rockoff, 2004; Rivkin, Hanushek and Kain, 2005) and their impact persists through adulthood (Chetty et al., 2011; Chetty, Friedman and Rockoff, 2014*b*). Attracting and retaining high-quality teachers to the profession can have far-reaching positive effects on students. More attractive compensation packages are sometimes proposed as a tool to achieve this goal. The salary schemes used in most US public schools, however, do not allow for the payment of financial rewards for effectiveness. If allowed to determine salaries in a more flexible way, could school districts improve the quality of their teaching workforce? Answering this question has been challenging because variation in compensation schemes among public school districts is rare: The vast majority of districts pay teachers according to lock-step schedules, often very similar within a state.[1] This implies that all teachers with the same seniority and academic credentials are paid identically, regardless of their effectiveness or the demand for their labor (Podgursky, 2006).

This paper studies the consequences of flexible pay by taking advantage of a reform of collective bargaining, which generated unique variation in teachers' pay schemes across school districts in Wisconsin. In June 2011 the state legislature passed Act 10, a bill that discontinued collective bargaining requirements over teachers' salary schedules. Previously, each district was forced to negotiate its schedule with the teachers' union, and pay was determined solely by seniority and education. Act 10 gave districts full autonomy to determine compensation without union consent and allowed them to negotiate salaries with individual teachers.

Districts used this autonomy in multiple ways. Hand-collected data on districts' employee handbooks (documents listing district-specific workplace policies and procedures) reveal that approximately half of all districts took advantage of their new-found discretion and replaced seniority-based schedules with flexible salary schemes that allow for pay differences among teachers with similar seniority and academic credentials. I refer to these districts as "flexible pay" (FP). The other half, which I call "seniority pay" (SP), maintained the use of seniority-based schedules. Comparing these two sets of districts I show that, in the five years following Act 10: (i) FP districts raised salaries for high-quality teachers, (ii) high-quality teachers moved from SP to FP districts, and (iii) teacher quality increased in FP relative to SP districts, due to both an improvement in the composition of the workforce and an increase in teachers' effort.

The cross-district differences in pay schemes introduced by Act 10 create a unique setting to

[1] Other works have used other changes in various aspects of teachers' labor markets to learn about teacher supply and demand. For example, Hensvik (2012) studies the effect of private vouchers, Jackson (2009) examines the impact of school de-desegregation, and Fitzpatrick and Lovenheim (2014) study the impact of an early teacher retirement policy.

learn about the effects of changes in teacher pay. The identification of these effects, however, involves some challenges. First, post-expiration pay schemes were chosen by district administrators and could have been driven by unobservable district characteristics correlated with outcomes. To mitigate this concern I exploit the fact that districts were allowed to switch to flexible pay at different points in time. The collective bargaining agreements (CBAs) signed before Act 10, which mandated the use of a salary schedule, remained valid until their expiration; due to long-standing differences in the negotiation calendars, the CBAs of different districts expired in a staggered fashion between 2011 and 2013. To identify the effects of flexible pay I leverage the quasi-randomness of the timing of expiration and I perform event studies around the expiration of the CBAs. With this strategy, in order for any observed differences in outcomes between FP and SP districts to be driven by unobservables, the timing of the change in these unobservables would have had to coincide with the timing of the expiration.

A second challenge is that Act 10 was a large reform. Aside from changing teachers' salaries, it also increased employees' contributions to pensions and health care and reduced the power of unions. I show, however, that all these other changes took place immediately following the passage of the Act in 2011, and that the pay schemes were the only element that changed after the expiration of the CBAs. I also demonstrate that measures of union power and spending on healthcare and retirement were comparable across FP and SP both before and after Act 10, and that all the results are unchanged when controlling for these variables.

Analyses of salary data show that, following the expiration of the CBAs in FP districts, large differences in pay arose among teachers who would have been paid exactly the same amount under the pre-Act 10 regime. To shed light on what drove these differences I correlate pay with teachers' value-added (VA), a widely used test scores-based measure of effectiveness. Since the Wisconsin data only allow teachers and students to be linked up to the grade (due to the lack of classroom identifiers), I estimate VA exploiting teacher switches across grades and schools. I validate my estimator using data on teachers and students from New York City, which include classroom identifiers, and show that it is a strong and unbiased predictor of student achievement. Importantly, my main results also hold when I predict teacher effectiveness using observable characteristics rather than VA.

Event study estimates indicate that salaries of high-VA teachers rose more than those of low-VA teachers in FP districts after an expiration, but not in SP districts. Given that school districts in Wisconsin do not calculate VA nor use it to evaluate teachers, this finding suggests that districts can identify highly effective teachers and choose to pay them more when given the possibility of doing so.[2] Salaries rose even more for middle-school teachers with high VA, presumably because their outside option is higher.

The changes in pay schemes that followed the expiration of the CBAs could have changed teachers' incentives to work in a given district, potentially affecting each district's workforce composition. Consider for example the school districts of Appleton (FP) and Oshkosh (SP), located in the same commuting zone in eastern Wisconsin and whose pre-Act 10 agreements expired in 2011. Prior to Act 10, a teacher with a Master's degree and 4 years of experience would have earned between \$46,500 and \$49,000 in Appleton and between \$42,000 and \$49,000 in Oshkosh, according to each district's pay schedule. After the expiration of the CBAs, the same teacher could earn up to \$68,000 in Appleton, and only between \$39,000 and \$43,000 in Oshkosh. If salaries are related to teachers' quality in Appleton, this change in pay should have induced high-quality teachers to move from Oshkosh to Appleton, and low-quality teachers to move from Appleton to Oshkosh. Indeed, although in the four years prior to the reform only four teachers moved from Oshkosh to Appleton, in the four years after the expiration of the CBA ten teachers moved; all of them ranked above the median VA and experienced an average pay increase of 16 percent (\$6,500). By contrast, the five teachers who moved from Appleton to Oshkosh after the expiration all ranked below the median VA and did not experience any significant increase in pay.

Event studies of movers across districts around the expiration of the CBAs confirm these patterns. The VA of teachers who moved to a FP district after an expiration was more than one standard deviation higher compared with the VA of teachers who moved before the expiration; these teachers also had lower seniority and academic credentials, and enjoyed a significant pay increase upon moving. The VA of teachers who moved to SP districts, on the other hand, was not significantly higher, and these teachers did not experience any change in pay. By the same token, the VA of teachers who left public schools from FP districts after the expiration was 60 percent lower compared with VA of those who left SP districts. The changes in the composition of movers and leavers produced a 0.04 standard deviation increase in average teacher quality after each CBA expiration in FP relative to SP districts. This result is robust to the exclusion of districts whose CBAs expired in 2011. Taken together, these results demonstrate that higher pay

[2] Rockoff et al. (2008) and Jacob et al. (2018) find that schools are able to recognize talented applicants when given enough information.

is an effective tool to attract and retain talented teachers.[3]

Other than affecting the composition of the teaching workforce, the introduction of flexible pay also increased teachers' effort. To show this I allow the VA of each teacher to vary before and after Act 10, and I estimate the FP-SP difference in this time-varying measure around the expiration of districts' CBAs. I find that VA increased by 0.09 standard deviations in FP relative to SP districts, and I calculate that approximately one third of this increase can be ascribed to changes in effort. Student test scores also rose in FP relative to SP districts after a CBA expiration, by 0.06 and 0.04 standard deviations in math and reading respectively.

My findings indicate that the introduction of flexible pay in a subset of Wisconsin districts led to an improvement in the composition of the teaching workforce in those districts compared with the rest of the state. The magnitude of these changes is small because movements and exits of teachers tend to be rare events.[4] The composition of movers and leavers, however, changed quite dramatically within a short time period. This implies that the overall compositional change could become more pronounced in the future, as more low-quality teachers leave the market from FP districts and more high-quality teachers enter the profession, especially if pay becomes more strongly correlated with teacher effectiveness over time.

This scenario, however, assumes that SP districts remain with seniority pay in the long run. If *all* districts switch to flexible pay, the effects on teacher composition and effort might be very different. On the one hand, when quality is rewarded at the same rate everywhere teachers would have fewer incentives to sort across districts; any compositional changes would likely be driven by either exits of low-quality teachers or entry of high-quality teachers. While my results indicate that flexible pay induces low-quality teachers to exit, its effects on the supply of new teachers in the medium and long run are less clear. [5] On the other hand, a statewide introduction of flexible pay could induce teachers in all districts to raise their effort in the classroom. Lastly, if certain teachers have a comparative advantage working with certain types of students, flexible pay could help districts attract and retain exactly those teachers they need the most, raising the comparative advantage of the whole school system. An analysis of the general-equilibrium effects of flexible pay which encompasses all these mechanism is left to future research.

This paper makes three main contributions. First, it is among the first to study the effects

[3] This result is in line with Johnston (2020).

[4] This finding is confirmed by Mansfield (2015) and Feng and Sass (2017), among others.

[5] Tincani (2020) shows that, when introduced in the Chilean public school sector, teacher merit pay increases student achievement by attracting talented teachers into public schools. Kraft et al. (2019) show instead that the recent accountability reforms passed across US states have depressed the supply and quality of new teachers.

of a newly-available, large-scale policy which gave school districts flexibility over teacher pay. Previous studies have been limited to small bonuses awarded on top of regular pay (Hanushek, Kain and Rivkin, 2004; Clotfelter et al., 2008; Dee and Wyckoff, 2015), limited cross-sectional variation in salaries (Stinebrickner, 2001; Boyd et al., 2013), and across-the-board salary increases (Figlio, 2002). Other works have exploited differences in teachers' outside option (Hensvik, 2012; Britton and Propper, 2016) as well as episodes of decentralization of pay decisions, using evidence from Sweden (Willén, 2018) and England (Burgess, Greaves and Murphy, 2019).

This paper can also be seen as an exploration, in the personnel economics tradition, of how pay affects the selection and incentives of an important class of workers (Lazear, 2000*a*,*b*; Bandiera, Barankay and Rasul, 2005; Abramitzky, 2009; Khan, Khwaja and Olken, 2015). While financial incentives for teachers have had a significant impact on student achievement outside the US, evidence from the US is mixed (see Jackson, Rockoff and Staiger, 2014; Neal et al., 2011, for a review).[6] This paper also provides new evidence that school districts are willing to compensate high VA teachers when given the opportunity to do so, and that teachers respond to these incentives by exerting more effort.

Lastly, this paper is one of the first to study the effects of a recent *decline* in the powers of teacher unions; most existing studies of have instead focused on increases in unionization (Eberts and Stone, 1987; Hoxby, 1996; Lovenheim, 2009; Lovenheim and Willén, 2019).[7] The effects of a decline in unionization on teachers' labor markets are particularly interesting in the aftermath of *Janus v. AFSCME*, as more states could be affected by this type of policy in the future.

# I Teacher Compensation Before and After Act 10

In most US public school districts teacher salaries are determined using a salary schedule, based on teaching experience and academic credentials (Podgursky, 2006, and Appendix Figure A1). In states with collective bargaining (CB) for public sector employees, these schedules are negoti-

[6]Studies conducted in India (Muralidharan and Sundararaman, 2011; Duflo, Hanna and Rya, 2012), Israel (Lavy, 2002, 2009, 2020), England (Atkinson et al., 2009), and Kenya (Glewwe, Ilias and Kremer, 2010) have shown positive effects of teacher financial incentives on students. In the US, however, some studies have found positive effects (Ladd, 1999; Figlio and Kenny, 2007; Sojourner, Mykerezi and West, 2014; Imberman and Lovenheim, 2015; Dee and Wyckoff, 2015; Brehm, Imberman and Lovenheim, 2017) while others have found none (Dee and Keys, 2004; Figlio and Kenny, 2007; Springer et al., 2011; Goodman and Turner, 2013; Fryer, 2013).

[7]Notable exceptions are Han (2016), Litten (2016), Roth (2017), and Baron (2018), who study the effects of recent episodes of de-unionization on outcomes such as teacher turnover, teacher salaries, retirement, and student achievement.

ated between school districts and teachers' unions and are part of a CBA.[8] CBAs usually prevent districts from adjusting pay at the individual level; experience and education are the only determinants of salaries, and pay is not directly related to teacher effectiveness (Podgursky, 2006).

### I.A Wisconsin's Act 10

In 1959, Wisconsin became the first state to introduce CB for public sector employees (Moe, 2013). Teachers' unions have since gained considerable power and have been involved in negotiations with school districts over the key aspects of a teaching job.[9] Until 2011, teacher pay was set using salary schedules, part of each district's CBA.

On June 29, 2011 the state legislature passed the Wisconsin Budget Repair Bill, also known as Act 10. Intended to address a projected $3.6 billion budget deficit through cuts in public-sector spending, Act 10 introduced a number of changes for teachers' unions, school districts, and their employees. First and most importantly, Act 10 limited the scope of salary negotiations to base pay, preventing unions from negotiating the salary schedules and allowing school districts to set pay more flexibly. Second, it capped the annual growth in base pay to the rate of inflation. Third, it requires unions to hold yearly recertification elections requiring the absolute majority of all employees in the bargaining unit, it limits the validity of future CBAs to one year, and it prohibits the automatic collection of union dues from employees' paychecks.[10] Lastly, Act 10 raised employees' contributions to pensions and health care. In July 2011, the state also passed Act 32, which reduced state aid to school districts and decreased their revenue limit.[11]

**Timing of Activation of Act 10's Flexible Pay Provisions** Even if the provisions of Act 10 went into effect immediately, districts became able to use their newly acquired flexibility at different points in time. The two-years-long CBAs stipulated between each district and the teachers' union prior to 2011 remained valid until their expiration; because districts had been on different negotiation calendars starting from several years prior to Act 10, the timing of these expirations differed. For a majority of the districts and 81.9 percent of all teachers the CBAs expired in 2011. For five districts, employing 11.6 percent of all teachers and including the large urban district of

[8] In states without CB, salary schedules are instead typically determined at the state level (e.g. Georgia). Schools are generally unionized on a district-by-district basis.

[9] 428 public school districts in Wisconsin typically serve either one city or one or more towns and villages. Each district enrolls an average of 1,900 students. Sixteen urban districts enroll 15,000 students per district on average (with Milwaukee Public Schools enrolling 67,000 students and the Madison Metropolitan School District enrolling 26,500 students), 63 suburban districts enroll 3,000 students per district, and 344 rural districts enroll 1,000 per district.

[10] Union membership dropped by nearly 50 percent in Wisconsin in the 5 years after the passage of Act 10 (Belkins and Maher, 2012).

[11] Revenue limits represent the maximum a district can raise through general state aid and local property taxes.

Milwaukee and the small rural district of Clintonville, they expired in 2012.[12] Lastly, for three districts and 6.5 percent of teachers, including the school district of Madison and the smaller suburban district of South Milwaukee, the CBAs expired in 2011 but before the activation of Act 10. These districts were thus able to negotiate a new CBA before Act 10 went into effect and their final agreement expired in 2013. Figure 1 summarizes the timing of expiration of districts' pre-existing CBAs.

**Act 10 and Teacher Salaries: Flexible Pay vs. Seniority Pay** With salary schedules no longer part of union agreements, upon the expiration of their CBAs school districts gained the possibility to reward teachers for attributes other than seniority and academic credentials, and to adjust salaries on an individual basis without union consent.

To check whether districts took advantage this newly gained flexibility I collected school districts' employee handbooks, documents which list the duties and rights of all teachers and which, until 2011, contained the schedule negotiated between the district and the union (these data are described in Section II). As of 2015, approximately half of all districts still included a schedule in their handbook and did not mention any other bonuses or increments. I call these seniority-pay districts (SP). The remaining districts, on the other hand, did not list any schedule. I refer to them as flexible-pay districts (FP).

The Racine Metropolitan School District and the Green Bay Area Public School District, among the state's largest urban districts, are examples of a SP district and a FP district, respectively. Racine's 2015 handbook contained a salary schedule and specified that movements along steps and lanes were to be determined solely on the basis of seniority and academic credentials (Appendix Figure A1).[13] Green Bay's 2015 handbook, on the other hand, did not contain a schedule and explicitly stated that "[t]he District will determine the starting salary for a new employee."[14] This language, common among FP districts, refers to districts' full autonomy to set teacher pay on an individual basis and to adjust it every year as they see fit.

# II Data and Measurement

The main data set contains information on the universe of Wisconsin teachers, linked to student test scores to calculate teacher VA. I combine it with information on districts' post-Act 10 salary

[12]For example, the school district of Janesville negotiated a contract in March 2008 (https://www.schoolinfosystem.org) and one in September 2010 (https://www.tmcnet.com).

[13]See the Racine School District website (http://www.rusd.org) for the most recent version of its teacher salary schedule.

[14]See the Green Bay Area Public School District website (http://www.gbaps.org) for the most recent version of its employee handbook.

schemes, drawn from employee handbooks, and with information on the expiration dates of districts' CBAs, obtained from a variety of sources. Data are reported by academic year, referenced using the calendar year of the spring semester (e.g. 2007 for 2006-07).

**Teacher Data** Information on the population of Wisconsin teachers comes from the *PI-1202 Fall Staff Report - All Staff Files* for the years 2007–2016, made available by the Wisconsin Department of Public Instruction (WDPI).[15] These files list all employees of the WDPI in each year and include personal and demographic information, education, years of teaching experience, and characteristics of job assignments (including total salary, grades and subject taught, full-time equivalency (FTE) units, and school and district identifiers). I restrict the sample to non-substitute teachers with FTE above 50, in FP and SP districts with non-missing CBA expiration dates.[16]

**Student Test Scores and Demographics** Student-level data include math and reading test scores in the Wisconsin Knowledge and Concepts Examination (WKCE, 2007–2014) and the Badger test (2015–2016), for all students in grades 3 to 8, as well as demographic characteristics such as gender, race and ethnicity, socio-economic (SES) status, migration status, English-learner status, and disability.[17]

**CBA Expiration Dates** I collected information on districts' pre-Act 10 CBAs from three main sources. The first are districts' pre-Act 10 union contracts. The second are school boards' meeting minutes from 2011, 2012, and 2013; these documents describe whether each district's CBA was set to expire in 2011, whether an extension was granted, and for how long. The third are local newspaper articles from 2011; many of these articles reported on the negotiations taking place and offered enough information to discern when the district's agreement was slated to expire. Using these three sources, I was able to obtain expiration and extension dates for 211 out of 426 school districts, employing 79 percent of all teachers. I give priority to information from union contracts, complementing it with the other two sources when unavailable.

**Employee Handbooks and Salary Schedules** I collected information on districts' pay schemes from their 2015 employee handbooks, available for 224 out of 428 districts and for 164 districts

[15]WDPI (2018*a*), complemented with WDPI (2015) and WDPI (2018*c*).

[16]I exclude long- and short-term substitute teachers, teaching assistants and other support staff, and contracted employees since salaries for these workers are calculated differently from those of permanent teachers. Due to evident mistakes in the reporting of salary information, I discard information for teachers in the school district of Kenosha, as well as for those in the school district of Milwaukee for the year 2015.

[17]The WKCE was administered in November of each school year, whereas the Badger test was administered in March. To account for this change, for the years 2007–2014 I assign each student a score equal to the average of the standardized scores for the current and the following year. WDPI (2018*d*).

with CBA information.[18] I classify a district as SP for the entire post-Act 10 period if its 2015 handbook contains a salary schedule and does not mention rewards for performance or merit, and as FP otherwise. If the handbook contains a schedule but also mentions bonuses linked to performance, I classify the district as FP. The final sample contains 74 FP districts, 90 SP districts, and covers 72 percent of all teachers.

**Other Data** District-level covariates include budget data from the WDPI, including revenues by source and expenditures by item, available for the years 2008–2015 (WDPI, 2018*b*), and information on union election outcomes from records of the WERC (2020).

## II.A Measurement: Teacher Value-Added

I measure teacher quality using value-added (VA), defined as a teacher's effect on test scores conditional on other determinants of achievement (such as past test scores, student demographics, and school effects). Albeit not a perfect measure (Rothstein, 2010), VA is generally considered a good signal of a teacher's effectiveness (Rockoff, 2004; Rivkin, Hanushek and Kain, 2005; Kane and Staiger, 2008; Chetty, Friedman and Rockoff, 2014*a*).[19] The starting point for the estimation of VA is the following model of achievement:

$$A_{kt} = \beta X_{kt} + \nu_{kt}, \text{ where } \nu_{kt} = \mu_{i(kt)} + \theta_{c(kt)} + \varepsilon_{kt} \tag{1}$$

$A_{kt}$ is a standardized measure of test scores for student $k$ in year $t$, $X_{kt}$ is a vector of student and school-specific controls, and $i(kt)$ denotes student $k$'s teacher in $t$.[20] VA is the estimate of $\mu_{i(kt)}$, the teacher-specific component of test score residuals.

VA is usually estimated using datasets containing classroom identifiers, which allow students to be linked to the teachers who taught them. Until 2017, the WDPI did not record classroom identifiers. This implies that I can only link teachers and students up to the school and grade. To deal with this data limitation, I adapt the empirical Bayes estimator of Kane and

[18] Handbooks are published on each district's website. Unclassified districts (i.e., those for which handbooks are not available) either do not have a website or do not make their handbook public. Appendix Table A2 compares FP and SP districts with unclassified districts. The latter are smaller, enroll more disadvantaged students, pay lower salaries, and are disproportionately located in rural areas.

[19] A growing body of evidence (Kraft, 2017; Jackson, 2018; Petek and Pope, 2016) shows that teachers can affect a large host of student outcomes beyond test scores. Here, I restrict my attention on the effects on test scores due to the unavailability of other outcomes.

[20] The vector $X_{kt}$ includes the following: school and grade-by-year fixed effects; cubic polynomials of past scores interacted with grade fixed effects; cubic polynomials of grade average past scores, interacted with grade fixed effects; student $k$'s demographic characteristics (gender, race and ethnicity, disability, English-language earner status, and socioeconomic status); grade average demographic characteristics; and the student's socioeconomic status interacted with the share of low-socioeconomic status students in her grade and school in $t$.

Staiger (2008) to match the structure of the data, and I leverage teacher turnover across grades and schools over time for identification (as in Rivkin, Hanushek and Kain, 2005, who face a similar challenge using data from Texas).

I begin by estimating $\beta$ in equation (1) via OLS. I then calculate average OLS residuals $\bar{\nu}_{gst}$ for each grade $g$, school $s$, and year $t$. Given $\bar{\nu}_{gst}$ and teachers' grade and school assignments, I can construct $\bar{\nu}_{it}$ for each $i$ and $t$. Teacher $i$'s VA is then

$$VA_i = \bar{\nu}_i \left( \frac{\sigma_\mu}{Var(\bar{\nu}_i)} \right)$$

where $\bar{\nu}_i = \sum_t w_{it} \bar{\nu}_{it}$ is a weighted average of $\bar{\nu}_{it}$, with weights function of the number of students in teacher's $i$ grade and school in year $t$, $n_{it}$, relative to other years: $w_{it} = n_{it} / \sum_t n_{it}$.[21] The quantity in parentheses is a shrinkage factor, which helps account for the fact that residuals are measured with noise. The numerator of the shrinkage factor is the variance of $\mu_i$, calculated as $\sigma^2_\mu = Cov(\bar{\nu}_{it}, \bar{\nu}_{it-1})$.[22]

**Identification** The intuition behind this approach can best be grasped by considering the "teams" of teachers in each $g$, $s$, and $t$. The empirical model implies that a team will have a high average performance (higher $\bar{\nu}_{gst}$) when it includes a high-VA teacher. With multiple years of data and in the presence of teacher turnover, the correlation between changes in team performance over time and movements of teachers across teams allows me to identify high- and low-VA teachers. In principle, if all possible combinations of teacher teams were observed, one could identify the VA of all teachers. In the absence of this, the VA of a teacher can be separately identified if she switches grade or school or if other teachers in her team switch. Conversely, if two or more teachers are always in the same team, their VA will not be separately identifiable and each of them will be assigned an average of their "true" VA. Teachers for whom VA ca be separately identified represent 70 percent of the whole sample; for a remaining 10 percent VA cannot be separately identified from that of another teacher, and for 20 percent it cannot be separately identified from that of two or more teachers. Appendix B illustrates the identification argument with a simple example.

[21]Given that I do not observe classrooms, I make the implicit assumption that $\theta_c$ is zero for all $c$. An alternative approach would be to assume $E(\theta_c) = 0$ and to set $\sigma^2_c$ to a constant. The qualitative results from my empirical analysis would be largely unchanged, as $\sigma^2_c$ only enters the shrinkage factor and both the composition and effort analyses shown below use "unshrunk" versions of VA.

[22]While the use of the shrinkage factor improves the consistency of the estimates and reduces attenuation bias when VA is used as an explanatory variable in empirical models, it leads to biased estimates when VA is used as the dependent variable. In the latter case, I use an "unshrunk" version of VA (as done by Chetty, Friedman and Rockoff, 2014*a*), simply equal to $\bar{\nu}_i$.

**Limitations of VA Estimates and a Validation Exercise** The use of grade-school (rather than classroom) residuals to estimate VA overcomes a problematic form of within-school selection, which occurs when children are not randomly assigned to classrooms.[23] My VA estimates, however, are likely to be noisier than estimates obtained using classroom links, since the VA of a given teacher could be a function of the achievement of students she never taught and the VA of some teachers cannot be separately identified from that of their colleagues. Measurement error could lead to bias if it is correlated with the other variables in my empirical models. This could occur, for example, if estimates are more precise for teachers who move and if movements are not random.

To assess the ability of my VA estimates to capture teacher quality, I use data from New York City (NYC) teachers and students (which include classroom links) and I compare the VA obtained with the standard approach of Kane and Staiger (2008) with the VA obtained with the approach used in this paper. The results from these tests (detailed in Appendix B) indicate that, although noisier, my estimates explain a substantial portion of the variance in test scores and represent forecast-unbiased estimates of both standard VA and future student achievement. Furthermore, the noise contained in the VA estimates is uncorrelated with student and teacher observables.[24] The main results of the paper also hold when, instead of using VA as a measure of teacher quality, I predict teachers' performance using observable characteristics (Appendix Table A15 and Figure A7).[25]

VA estimates are available for 25,021 teachers of math and reading in grades 4 through 8, including the final sample of 18,856 teachers in 164 FP and SP districts with non-missing CBA expiration dates (see Appendix Table A3 for a summary). My empirical analyses use two VA measures. The first is *ex ante* VA, calculated using test scores for the years 2007–2011 and used to single out the effects of Act 10 on teachers' composition. The second is a time-varying measure, allowed to differ before and after Act 10 for each teacher and used to study changes in effort.[26]

[23]The use of grade-school estimates is essentially equivalent to an instrumental variable estimator based on grade rather than on classroom assignment (Rivkin, Hanushek and Kain, 2005).

[24]See Appendix Figure B2 for a distribution of VA, Figure B3 for a test of forecast-unbiasedness of the standard VA, and Table B1 for a test of forecast-unbiasedness of test scores.

[25]To perform this test I make use of the NYC teacher and student data to predict teacher quality (measured either as VA, estimated using classroom links and the procedure of Kane and Staiger, 2008, or as students' test scores conditional on all the covariates used as controls in the VA model). I then use estimates from this prediction model to construct two alternative quality measures for Wisconsin teachers (estimates of these prediction models are shown in Appendix Table A14. In Appendix Table A15 I examine how these new measures of quality changed after a CBA expiration in FP relative to SP districts, confirming the results of the main tests based on VA. Event studies are shown in Appendix Figure A7.

[26]By construction, *ex ante* VA is only available for the subsample of teachers who were already in the system before 2011. Appendix Table A4 shows that teachers with *ex ante* VA have higher experience than teachers without VA; *ex post* VA, however, is not statistically different among these two groups of teachers.

# III Indentifying The Effects of Changes in Pay Schemes

The goal of my empirical strategy is to isolate the effects of changes in the structure of teacher salaries generated by Act 10 on pay, the composition of the teaching workforce, teachers' effort, and student achievement. Doing so requires overcoming a set of challenges.

**Other provisions of Act 10** The first challenge is that Act 10 was a large reform, which affected teachers in many ways beyond the change in pay schemes: it changed employees' health and retirement benefits and reduced the power of teacher unions. A simple comparison of outcomes before and after the reform would likely confound the effects of changes in pay structures with the effects of all these other changes.

To overcome this issue I take advantage of the fact that, while all the other provisions of Act 10 were activated immediately after the passage of the law in June 2011, districts were only allowed to discontinue the use of the salary schedules after the expiration of existing CBAs. The timing of these expirations varied across districts (Figure 1), reflecting long-standing misalignments in the negotiation calendars. For example, while most districts typically negotiated agreements bi-yearly on odd years, the school district of Janesville negotiated contracts in March 2008 and September 2010.[27] Off-calendar districts include both large, urban districts like Milwaukee and Madison and smaller, suburban and rural districts like Clintonville and South Milwaukee. The timing of the expiration is uncorrelated with observable district characteristics (Appendix Table A1).[28]

To confirm that all other provisions of Act 10 had an effect in 2011, regardless of the timing of expiration of districts' CBAs, Appendix Figure A2 compares time trends of various district attributes likely affected by Act 10 (such as expenditures on teacher salaries, retirement, and health benefits, and trends in the share of districts whose unions managed to recertify, top panel) with event studies of the same variables around a CBA expiration, controlling for year effects (bottom panel). If the assumption that these variables were unaffected by the CBA expiration holds, one would observe a discontinuity in the trends between 2011 and 2012, but no discontinuity after the expiration of districts' CBAs when controlling for year effects. The evidence in the figure confirms this. As a result, event studies of outcomes around the expiration of the CBA agreements which control for years after Act 10 should isolate the effects of changes in pay

[27] See https://www.schoolinfosystem.org and (https://www.tmcnet.com.

[28] The table shows OLS estimates of a number of characteristics of districts, teachers, and students, measured in 2011, on indicators for the CBAs expiring in 2011, 2012, and 2013. None of these characteristics predict the expiration year with the exception of the indicator for urban districts, which predicts an expiration in 2012.

schemes.

**Endogeneity of the choice of pay schemes** The second challenge is that the ultimate decision on whether to discontinue the use of a salary schedule was made by school district administrators, and it could be endogenous.[29] A comparison of outcomes between FP and SP districts over time could therefore yield biased results if the choice of the pay scheme is correlated with other time-varying, unobserved school district characteristics that directly affect the outcomes.

This challenge, too, can be addressed exploiting the exogeneity of the timing of expiration of districts' CBAs. A comparison of outcomes between FP and SP districts around each expiration allows me to isolate the effects of changes in pay schemes, provided that the timing of changes in any unobservables does not exactly coincide with the timing of the CBA expirations. If the timing of the expirations is as good as random, any bias from unobservables should play at most a small role. I confirm this by estimating bounds to the main effects that account for unobservables (as in Altonji, Elder and Taber, 2005) and by showing that my results hold when I exclude districts whose agreements expired in 2011.

# IV Salary Responses to Act 10

Act 10 allowed districts to depart from the salary schedules and to pay different salaries to teachers with the same seniority and education. An increase in pay differences among similar teachers in FP districts is evident in Appendix Figure A3, which plots median salaries and 10-90 percentile ranges by teacher experience in the school districts of Green Bay (a FP district, top panel) and Madison (a SP district, bottom panel). Before Act 10, the salary distribution was very similar across the two districts. For example, median pay for teachers with four to six years of experience was equal to \$42,345 in Green Bay (with a range of \$6,000) and to \$43,092 in Madison (with a range of \$8,464). After Act 10, pay dispersion significantly increased in Green Bay (with a range of \$13,700), while it stayed stable in Madison (with a range of \$8,549).

To more systematically quantify the changes in pay dispersion across all districts, I perform an event study of the coefficient of variation (CV) of the salaries of similar teachers around each district's CBA expiration. The CV is calculated as the ratio between the standard deviation and the mean for teachers in the same district, with the same experience and the same education. The CV was on a flat trend the years leading to a CBA expiration, and it increased by 0.009 two years after the expiration (or 10 percent compared with an average of 0.09 in the years prior to

[29] Possible drivers of this decision include fiscal concerns, the desire to compensate high-quality teachers or to preserve teachers' morale, and increased pressure to compete with other districts for talent (Kimball et al., 2016).

an expiration, Figure 2, top panel, solid line). The increase is similar when restricting attention to teachers who never move across districts (dashed line), indicating that the salary dispersion is not just driven by new hires.

The increase in pay dispersion was largely driven by FP districts. An event study of the difference in the CV between FP and SP districts around a CBA expiration shows that this difference was on a flat trend in the years leading to an expiration, and it increased by 0.009 in the year following the expiration (or 10 percent compared with a pre-expiration average of 0.087 for SP districts, Figure 2, bottom panel). These estimates suggest that FP districts used their newly-acquired flexibility to compensate teachers for attributes not directly rewarded by a standard schedule.

**Salaries and Teacher Quality** What drove the post-Act 10 increase in salary dispersion in FP districts? To answer this question, the ideal test would estimate the correlation between pay and those teacher attributes, not rewarded under seniority pay, that districts could compensate under a FP scheme. These include (but are not limited to) effectiveness, progress, leadership, and professional development. Most of these attributes, however, are only observable to principals and other school administrators. I hence settle on a more modest task and study the correlation between salaries and teacher VA, conditional on experience and education. While districts do not observe nor explicitly use VA to evaluate teachers, this measure could be correlated with other attributes that districts can observe and value.

I estimate this correlation using the following model:

$$\ln(w_{it}) = \delta_0 VA_{it} + \delta VA_{it} * \mathbb{1}(t > Exp_{j(it)}) + \beta X_{it}^{w} + \theta_{j(it)t} + \varepsilon_{it} \tag{2}$$

where $w_{it}$ is the salary earned by teacher $i$ in year $t$, $VA_{it}$ is teacher VA (allowed to vary before and after 2011 and standardized to have mean 0 and variance 1) and $Exp_j$ is the year of expiration of district $j$'s CBA. The index $j(it)$ denotes the district in which $i$ teaches in $t$. The vector $X_{it}^{w}$, which includes indicators for years of experience interacted with indicators for the highest education degree and with an indicator for years after 2011, allows me to examine the correlation between salaries and VA among teachers with comparable attributes. The inclusion of a vector of district-by-year fixed effects $\theta_{jt}$ allows me to compare teachers who work in the same district in each year. I estimate the equation using OLS; since VA is an estimated variable, I calculate bootstrapped standard errors clustered at the district level. In this specification, $\delta_0$

estimates the correlation between salaries and VA before each district's CBA expiration and $\delta$ estimates the change in this correlation after the expiration.

In FP districts, the correlation between salaries and VA is very small and indistinguishable from zero before the expiration of districts' CBA, and it becomes positive and significant after the expiration (with an estimate of $\delta$ equal to 0.004, Table 1, column 1, significant at 5 percent). This implies that a one-standard deviation higher VA is associated with a 0.4 percent higher salary. In SP districts, on the other hand, the estimate is virtually zero (Table 1, column 2, with a p-value equal to 0.83; the difference between FP and SP districts is shown in column 3 and is significant at 5 percent). Estimates of $\delta$ are larger for middle-school teachers in FP districts (this might reflect a higher outside option for these teachers, columns 3-6). Estimates are robust when restricting the sample to tenured teachers (with at least three years of experience, Appendix Table A5), teachers in schools and grades with at most three teachers per subject and grade (where the noise in the VA estimates is the smallest, Appendix Table A7, columns 1-3), and teachers whose VA is exactly identified from that of their colleagues due to teacher turnover (Appendix Table A7, columns 4-6). Estimates are also robust to the exclusion of the large districts of Madison and Milwaukee (Appendix Table A6) and when controlling for teaching assignment (grade and subject, Appendix Table A8).

To assess how the correlation between salaries and VA changed over time and to check for the existence of pre-trends, I allow the parameter $\delta$ to vary by time-to-CBA expiration. Estimates of this specification, shown in Figure 3, are indistinguishable from zero and very similar in both FP and SP districts in the years leading to an expiration. In line with Table 1, they become positive and statistically significant in FP districts after an expiration, reaching 0.7 percent of a standard deviation the year following the expiration (Figure 3, solid line), while they remain close to zero in SP districts (Figure 3, dashed line). Estimates from a semi-parametric version of equation (2) show that the increase in the correlation in FP districts is driven by teachers with VA in the top three quintiles (Appendix Figure A4).

Although positive, estimates of $\delta$ are small in magnitude. It might therefore seem surprising that such small changes in salaries produce any behavioral responses. It should be emphasized, however, that districts do not use VA when making decisions over teacher pay. In fact, school districts do not even calculate VA; interviews with superintendents reveal that post-Act 10 schemes in FP districts are designed to reward teachers for a number of attributes, including (but not limited to) their preparation, leadership, learning, and professional development.[30] If these characteristics have a positive but small correlation with VA, this could result in low estimates of $\delta$ due to attenuation bias.[31] Estimates of $\delta$ should therefore be interpreted as evidence that districts use their post-Act 10 pay flexibility to reward teacher characteristics that are, at least to some extent, positively correlated with VA, rather than as estimates of the actual salary differences that teachers experience under the new pay scheme.

# V Movements, Exits, and Changes in Workforce Composition

How did teachers respond to the cross-district differences in pay that arose after the CBAs expired? Here, I focus on movements from one school district to another and exits from the state's public schools, and I briefly discuss entry into the profession. I then quantify the implications of these responses for the composition of the teaching workforce across districts.

## V.A Teachers' Movements Across Districts

Teacher movements across districts became significantly more frequent after Act 10, increasing from 1.3 percent per year until 2011 to 2.9 percent after 2011 (Figure 4, top panel). The timing of this increase appears in line with the expiration of districts' CBAs, rather than just with the passage of Act 10 in 2011 (middle panel).[32] Cross-district movements increased significantly more across districts of different type (from FP to SP or vice versa, a 3-fold increase) than across districts of the same type (a 112 percent increase, Figure 4, bottom panel).

Were these movements driven by the differences in pay schemes across FP and SP districts? The bottom panel of Figure 4 shows an event study of mobility by type of district of origin and destination (FP or SP). Movements across districts of different type increased by a large 1.9 percentage points four years after a CBA expiration (a 3-fold increase, significant at 1 percent). Movements across districts of the same type, on the other hand, only increased by 0.9 percentage points (a 112 percent increase, p-value equal to 0.14, Figure 4, bottom panel).

As demonstrated in the previous section, FP districts compensate teachers for their quality, whereas SP districts only reward them for seniority and academic credentials. This should create

[30] Interviews with superintendents of a subset of 12 FP and SP districts were conducted by phone in December 2017.

[31] Papay and Kraft (2015) show that professional development is associated with improvements in teacher quality. Dobbie (2011) demonstrates that teacher leadership is a good predictor of future student test scores among Teach for America corps members. Jackson, Rockoff and Staiger (2014) provide a review of the literature on teacher attributed associated with VA.

[32] An event study of moving rates around an expiration that accounts for year effects indicates that moving rates increased by 1.5 percentage points one year after an expiration and by 4.6 percentage points four years after an expiration, relative to before (Figure 4, middle panel).

incentives for higher VA teachers (especially those with low seniority and academic credentials) to move to FP districts, where they would enjoy higher pay, and for lower-VA teachers with high seniority and academic credentials to move to SP districts.

To test this hypothesis I study how the attributes of teachers who moved to FP and SP districts changed after a CBA expiration. I focus on three attributes: VA, experience, and having a postgraduate degree (Master's or PhD). I estimate the following equation, separately for movers to FP and SP districts:

$$Y_{it} = \beta \mathbb{1}(t > Exp_{j(it)}) + \gamma X_{it} + \xi Z_{j(it)t} + \tau_t + \varepsilon_{it} \tag{3}$$

where $Y_{it}$ is teacher $i$'s characteristic in year $t$, and $Exp_j$ is the year of expiration of the CBA agreement of district $j$. A vector $X_{it}$ of teacher observables, such as type of district they were teaching in at $t-1$ (FP or SP), accounts for the different incentives to move based on the district of origin. A vector of district characteristics $Z_{jt}$, such as per teacher expenditure on various budget items, per pupil expenditure, and measures of union power, controls for the effects of other provisions of Act 10 on the composition of movers. In this specification, the coefficient $\beta$ captures the post-expiration change in $Y_{it}$ for the teachers who move to each type of district.

OLS estimates of equation (3) indicate that teachers who moved to FP districts after a CBA expiration had a 1.12 standard deviations higher VA relative to those who moved before the expiration (Table 2, panel A, column 1, significant at 1 percent). They also had 1.6 fewer years of experience (34 percent less compared with a pre-2011 average of 4.8, panel B, column 1, significant at 5 percent) and were 15 percentage points less likely to have a postgraduate degree (or 49 percent, panel C, column 1, significant at 5 percent). These estimates are robust to controlling for the type of district of origin (column 2). Movers to SP districts after a CBA expiration, on the other hand, have slightly lower VA and years of experience compared with movers before the expiration, although these differences are indistinguishable from zero (Table 2, panels A and B, column 2, p-values equal to 0.45 and 0.30 respectively), and are 8 percentage points (26 percent) more likely to hold a postgraduate degree (Table 2, panel C, column 2, significant at 5 percent). Columns 5 and 6 test for differences in the characteristics of movers to FP and SP districts using a difference-in-differences estimator. Importantly, in these specifications I control for an interaction between *FP* and an indicator for years after 2011, to account for any observable and unobservable factors, specific to FP and SP districts and whose timing coincides with the passage of Act 10, that could affect the selection of movers. (The inclusion of this control implies that $\beta$ is essentially estimated using the variation from districts districts whose agreements expired after 2011.) These estimates confirm that movers to FP districts after a CBA expiration have higher VA, lower experience, and are less likely to hold a postgraduate degree compared with movers to SP districts (estimates on *FP* $\times$ *post-CBA expiration*, Table 2, column 6, significant at 1, 10, and 1 percent respectively).

Event study figures of changes in these characteristics show little evidence of differential pre-trending and reveal that that the timing of the changes in these variables coincides with the timing of expiration of districts' CBAs (Figure 5).

**Salaries of Movers** To what extent were the sorting patterns emerging from Table 2 driven by the promise of higher pay for high-VA teachers in FP districts? I tackle this question by exploring the relationship between salaries and VA of teachers who move to FP and SP districts, in the years surrounding a move. I estimate the following equation on the sample of teachers who move at least once between 2007 and 2016:

$$\begin{aligned}\log(w_{it}) = \quad & \gamma X^w_{it} + \theta_{jt} + \sum_{k=-4}^{2} \beta^0_k \mathbb{1}(t - Y_{m(ij)} = k) + \sum_{k=-4}^{2} \beta^1_k VA_i \mathbb{1}(t - Y_{m(ij)} = k) \\ & + \sum_{k=-4}^{2} \beta_k VA_i \mathbb{1}(t - Y_{m(ij)} = k) * \mathbb{1}(Y_{m(ij)} > Exp_j) + \eta VA_{it} \mathbb{1}(Y_{m(ij)} > Exp_j) + \varepsilon_{it}\end{aligned} \tag{4}$$

where the variable $Y_{m(ij)}$ is the year in which teacher $i$ moves to district $j$, and $X^w_{it}$ and $\theta_{jt}$ are as in equation (2).[33] Normalizing $\beta_{-1}$ to zero, each parameter $\beta_k$ estimates the post-expiration change in salaries associated with a one-standard deviation higher VA $k$ years from the move.

OLS estimates of $\beta_k$ indicate that a one-standard-deviation higher VA is associated with a 2-percent higher salary upon moving for teachers who move to FP districts after an expiration, relative to before (Figure 6, solid line). Notably, no trends in salaries can be observed in the years leading to a move. A higher VA is instead not associated with any significant differences in salaries for movers to SP district after a CBA expiration (Figure 6, dashed line). These results provide suggestive evidence that, in the aftermath of Act 10, high-quality teachers were attracted to FP districts by the prospect of higher salaries.

[33] For teachers who move more than once between 2007 and 2015, I consider only the earliest move. The results are robust to using the latest move.

## V.B Exit from Public Schools

The increase in movements of teachers across districts after Act 10 was accompanied by a spike in the share of teachers who left Wisconsin public schools.[34] In at the end of 2010, 5.1 percent of teachers left; at the end of 2011, 9.0 percent left (Figure 7, top panel).[35] A significant part of this increase followed the expiration of the CBAs: Controlling for year effects, exit rates increased by 5 percentage points in the year following an expiration (Figure 7, bottom panel).

Which teachers decided to leave after the expiration of districts' CBA? The introduction of a pay scheme that rewards quality instead of experience and academic credentials should have induced teachers with lower VA, higher seniority, and better credentials to exit FP districts at a higher rate. To test this hypothesis I re-estimate equation (3) on the sample of teachers who exit public schools at the end of each year. To account for the effects of other teacher observables on the decision to leave and for early retirement, in these specifications I control for age fixed effects and for the other teacher characteristics not included in $Y_{it}$, alone and interacted with an indicator for the years after 2011. In this specification, the coefficient $\beta$ captures the post-expiration change in the characteristics of teachers who exit public schools from districts of each type, compared with teachers who left before the expiration.

OLS estimates indicate that teachers who exit FP districts after a CBA expiration have a 0.5 standard deviations lower VA relative to those who exit before the expiration, although this estimate is not distinguishable from zero (Table 3, panel A, column 1, p-value equal to 0.45). They also have 0.6 fewer years of experience (panel B, column 1, significant at 10 percent), and they are not differentially likely to have a postgraduate degree (panel C, column 1, p-value equal to 0.23). These estimates are robust to controlling for district characteristics (column 2). Teachers who exit SP districts after a CBA expiration, on the other hand, have a 0.26 standard deviations higher VA and 2.3 additional years of experience (Table 3, panels A and B, column 2, significant at 5 percent), and they are not differentially likely to hold a postgraduate degree (panel C, column 2, p-value equal to 0.23). Columns 5 and 6 test for differences in the characteristics of the teachers who exit from FP and SP districts in a difference-in-differences framework, controlling for the interaction between *FP* and an indicator for years after Act 10. These estimates confirm that teachers who exit FP districts after a CBA expiration have lower VA and fewer years of

[34]Exit rates are defined as the share of individuals who disappear from the records of employees in Wisconsin public schools from one year to the next. Reasons for exiting include retirement, dropping out of the labor force, or a move to a to private school or to another industry/occupation. The staff data does not allow me me to observe a teacher after she leaves, and I am thus unable to distinguish among these reasons.

[35]Part of this increase in exit rates was driven by teachers retiring early (Biasi, 2019).

experience (estimates on *FP* $\times$ *post-CBA expiration*, Table 3, panels A and B, significant at 10 and 5 percent respectively).

Event studies of changes in VA, experience, and academic credentials for teachers who exit from FP and SP districts show little evidence of differential pre-trends and confirm that that the timing of the changes in these variables coincides with the timing of expiration of districts' CBAs (Figure 8).

**Salaries of Exiters** Next, I test whether the disproportionate exit of low-quality teachers from FP districts was related to a decline in pay. I estimate the following model:

$$\begin{aligned} \log w_{it} &= \beta_0 e_{it} + \beta_1 e_{it} * \mathbb{1}(t \geq Exp_{j(it)}) + \beta_2 VA_{it} + \beta_3 VA_{it} * \mathbb{1}(t \geq Exp_{j(it)}) \\ &\quad + \beta_4 VA_{it} * e_{it} + \beta_5 VA_{it} * e_{it} * \mathbb{1}(t \geq Exp_{j(it)}) + \beta X^w_{it} + \theta_{jt} + \varepsilon_{ijt} \end{aligned} \tag{5}$$

where the variable $e_{it}$ equals one if teacher $i$ exits public schools at the end of year $t$ and $X^w_{it}$ and $\theta_{jt}$ are as in equation (2). I estimate this model separately for teachers in all districts and in FP and SP districts. In this equation, the parameter $\beta_1$ captures the change in salaries of teachers with average VA who leave after a CBA expiration, relative to stayers and to teachers who left before the expiration. Estimates of $\beta_5$ capture instead the extent to which this difference is related to teacher VA.

OLS estimates of equation (5) on all districts, shown in column 1 of Table 4, indicate that teachers with average VA who left after the expiration of a district's CBA did not experience a significantly different salary (with an estimate of *Exit* * *post-CBA expiration* equal to -0.003, Table 5, column 1, p-value equal to 0.53). Teachers with a one-standard deviation lower VA who left, however, experienced a 0.9 percent lower pay (with an estimate of *VA* * *exit* * *post-CBA expiration* equal to 0.009, Table 5, column 1, p-value equal to 0.15). The relationship between the VA of teachers who left and their pay is stronger in FP districts (with an estimate of *VA* * *exit* * *post-CBA expiration* equal to 0.017, Table 5, column 2, significant at 10 percent), and it is close to zero in SP districts (estimate equal to 0.002, Table 5, column 3, p-value equal to 0.58). Taken together, these estimates suggest that the disproportionate exit of low-quality teachers from FP districts was related to a decline in pay.

### V.C Entry Into the Teaching Profession

The third margin through which changes in pay schemes following Act 10 could affect the composition of the teaching workforce is a change in the supply of new teachers. While the share of new teachers per year was on a downward trend in the years leading to Act 10 (and equal to 2.4 in 2011), it increased rapidly after Act 10, possibly to fill in the larger number of vacancies opened by the teachers who left (Figure 9, top panel). The timing of these changes is in line with the expiration of districts' CBAs: Entry increased by 2.7 percentage points two years after an expiration, declining again in the following years (Figure 9, bottom panel).

Did the composition of the pool of individuals who chose to become teachers change after Act 10? On the one side, the changes in pay schemes introduced in FP districts after the expiration of the CBAs could have induced better or more motivated teachers to enter the market in these districts (Hoxby and Leigh, 2004; Rothstein, 2014).[36] On the other side, the overall decline in pay levels and in benefits that followed Act 10 could have made teaching less attractive in the eyes of prospective teachers, discouraging them from entering. It is also possible that, as of 2016, the supply of new teachers had not yet adjusted in response to the policy change: Becoming a teacher requires obtaining an education degree and a license, which takes time.

To isolate the effect of changes in pay schemes on the supply of new teachers, I again exploit differences in the expiration dates of districts' CBAs and compare new teachers in FP and SP districts in an event study setting. Unfortunately, VA is generally not available for new teachers; building this measure requires observing teachers over multiple years (Bitler et al., 2019). To partially capture the quality of new teachers I use measures of selectivity of the institution where they obtained their most recent degree, among the few correlates of teaching quality (Ballou and Podgursky, 1997; Hoxby and Leigh, 2004; Clotfelter, Ladd and Vigdor, 2010).[37] I focus on two metrics: the 25th percentile ACT English score of admitted students and an indicator for whether the institution performs selective admissions, both measured in 2010.

Figure 10 shows an event study of measures of college selectivity for new teachers around the year of expiration of districts' CBAs, separately for FP and SP districts. In these specifications I control for districts' expenditures, budget items, and measures of union strength. Both in FP and SP districts, selectivity measures are flat in the years leading to an expiration. After an expiration, the 25th percentile ACT score of entrants' BA schools declines in an almost identical way in SP and FP districts (Figure 10, panel A). The share of entrants with degrees from non-selective institutions slightly increases in FP districts and slightly decreases in SP districts; the FP-SP difference, however, is not distinguishable from zero (Figure 10, panel B).

[36] Hoxby and Leigh (2004) show that the decline in the entry rates of high-quality teachers in US public schools since 1960 can be attributed to an increased compression in wages caused by the rise in unionization. Rothstein (2014) demonstrates that higher salaries and lower tenure rates can improve the supply of new teachers.

[37] Information on college selectivity is from IPEDS (2018).

With the caveat that they are based on imperfect measures of teacher quality, these tests do not provide evidence of a differential change in the supply of new teachers in FP relative to SP districts following the introduction of flexible pay in FP districts. This, however, does not rule out the possibility that selection into teaching could change over a longer time period, giving prospective teachers enough time to make the appropriate educational investments.

### V.D Composition of the Teaching Workforce

Movements of teachers across districts and exits from public schools changed the composition of each district's teaching workforce. I quantify this change by comparing *ex ante* teacher VA in FP and SP districts before and after expiration of districts' CBAs. I estimate:

$$VA_i = \beta_0 FP_{j(it)} + \beta FP_{j(it)} * \mathbb{1}(t > Exp_{j(it)}) + \gamma X_{it} + \eta Z_{j(it)t} + \tau_t + \varepsilon_{ijt} \tag{6}$$

In this equation, the parameter $\beta$ captures the change in VA in FP relative to SP districts after Act 10.[38] Estimates of $\beta$, shown in Table 5, indicate that *ex ante* teacher VA increased by 0.02 standard deviations in FP districts compared with SP after Act 10 (Table 5, column 1, significant at 5 percent). Importantly, this estimate is robust and it increases to 0.057 standard deviations when controlling for *FP * post*, to account for any observable and unobservable changes in FP and SP districts following the passage of Act 10 (column 3, significant at 1 percent). Estimates are robust to the exclusion of districts whose CBAs expired in 2011 (Appendix Table A9, columns 3-4, and Appendix Figure A6, left panel).[39] Estimates are also robust when controlling for districts' budget items and measures of union strength (columns 4-5) and to the exclusion of the school districts of Milwaukee and Madison (Appendix Table A10).

To gauge the extent to which noise in the VA estimates affects these results, in Appendix Table A11 I restrict the sample to teachers in schools and grades with at most three teachers per subject (column 1) and teachers whose VA is exactly identified from that of their colleagues due to turnover (column 2). Estimates of $\beta$ are slightly larger and more precisely estimated. Further-

[38] When interpreting these estimates one should keep in mind that, in an event study where changes in the dependent variable are driven by movements of teachers across districts that are treated at different points in time, the SUTVA assumption could be violated due to treatment spillovers on not-yet-treated districts. The strategy used here, however, identifies the effects of flexible pay not only through a comparison of districts with different CBA expiration dates over time, but also through a comparison of FP and SP districts in each year. Because the differences in the pay schemes among FP and SP districts arose only after a CBA expiration, the sorting of movers prior to an expiration should have been the same in FP and SP districts. As a result, taking the difference in VA between FP and SP districts whose CBAs expired in the same years allows to account for these pre-treatment spillovers. This is evident in Figure 11, which shows no pre-trends in the FP-SP difference in ex ante VA in the years prior to an expiration.

[39] Given the small number of districts, in columns 3, 4, 7, and 8 of Appendix Table A9 I conduct inference using a wild cluster bootstrap and I present t-statistics in brackets.

more, the results from this test remain qualitatively similar when I predict teacher performance using a teacher's observable characteristics, instead of measuring it using VA (Appendix Table A15 and Figure A7).

Time-varying estimates of $\beta$ around the date of expiration of districts' CBAs, shown in Figure 11, are on a flat trend in the years leading to the expiration. They become positive at 0.06 the year after the expiration and remain high at this level four years after the expiration.

If the expiration date of districts' CBAs is as good as random, the difference in teacher composition across FP and SP districts around the time of expiration can safely be attributed to the introduction of flexible pay; for this difference to be driven by changes in unobservables, the timing of the change in these unobservables would have to be identical to that of each CBA expiration. To rule out this possibility, I follow Altonji, Elder and Taber (2005) and estimate an upper bound for the bias in $\beta$ driven by unobservables. This test relies on the assumption that the portion of a district's VA change due unobservables and the portion due to the observables included as controls in column 3 of Table 5 have the same relationship with the post-expiration pay scheme.[40] The upper bound for this bias equals -0.025 standard deviations of VA, which implies that, at a maximum, unobservables would lead me to underestimate the compositional changes driven by changes in the pay scheme.

While the estimated compositional improvement might seem small at a first glance, it should be noted that it is triggered by the introduction of only a small return to VA in FP districts. Moreover, this change is driven by movements and exits which, over a post-reform time horizon of only four years, are rare events. Nevertheless, the results presented above show large changes in the composition of movers and leavers even within such a short time period. The compositional change driven by the introduction of flexible pay could become larger in the long run as more and more teachers move or exit, especially if FP districts make pay even more dependent on teacher quality and less on seniority and education.

## VI Teachers' Effort and Student Achievement

Other than affecting the composition of the teaching workforce, the introduction of a pay scheme that rewards quality could also incentivize *all* teachers to exert higher effort, with potentially

[40] In practice, this test requires estimating the correlation between the unobservable component of the independent variable of interest (in this case, *FP*post-CBA expiration*) and the unobservable component of the dependent variable (Altonji, Elder and Taber, 2005, denote this correlation as $\rho$). This correlation can be estimated using the estimates of a regression of equation (6) (including all the controls) and a regression of *FP*post CBA expiration* on the controls, as in Altonji, Elder and Taber (2005). I estimate the correlation to be equal to -0.34.

large effects on students. To test this hypothesis, I re-estimate a version of equation (6) where I allow the VA of each teacher to vary between the pre- and post-reform periods. In this equation, the coefficient $\beta$ captures the *overall* change in teacher quality in FP relative to SP districts after the expirations of the CBAs, driven both by changes in composition and changes in effort.

OLS estimates of $\beta$ indicate that the VA of teachers in FP districts increased by 7.6 percent of a standard standard deviation after a CBA expiration compared with the VA of teachers in SP districts (Table 6, column 2, significant at 5 percent). Controlling for an interaction between *FP* and indicators for years after 2011 (column 3) and for characteristics of the teachers and the districts (column 4) yields a slightly less precise, but larger estimate of 0.09 (p-values equal to 0.15 and 0.05). Assuming that this overall change is simply the sum of a compositional change (shown in column 3 of Table 5) and a change in effort, this estimate implies that 37 percent of the overall increase in VA (shown in column 4 of Table 6) is due to changes in effort (0.090 - 0.057 divided by 0.090), whereas the remaining 63 percent is driven by changes in composition.

Time-varying estimates of $\beta$ in equation (6), shown in Figure 12, do not reveal any pre-trends and indicate that the increase in VA occurred immediately after a CBA expiration. Estimates are robust when restricting attention to districts whose agreements expired after 2011 (Appendix Table A9, columns 7 and 8, and Figure A6, right panel), to the exclusion of the school districts of Milwaukee and Madison (Appendix Table A12), and when restricting the sample to teachers in schools and grades with at most three teachers per subject (Appendix Table A11, column 3) and to teachers whose VA is exactly identified from that of their colleagues due to teacher turnover (Appendix Table A11, column 4).

To isolate changes in effort more directly, also I re-estimate equation (6) with teacher fixed effects. This estimate indicates that, within teacher, VA increased by 0.085 standard deviations after a CBA expiration for teachers in FP districts, relative to teachers in SP districts (Table 6, column 5, significant at 10 percent).

Taken together, these results indicate that a change in the pay scheme from one based on seniority and education to one that rewards quality affects both the composition of the teaching workforce and teachers' effort. The estimated large increase in effort is in partial contrast with the findings that financial incentives do not affect teachers' effort and productivity (Goodman and Turner, 2013; Fryer, 2013; de Ree et al., 2018), but in line with Macartney, McMillan and Petronijevic (2018). One should keep in mind, however, that my findings are based on a substantially different policy, which drastically and permanently changed the entire structure of teacher pay.

**Student Achievement** Increases in teacher VA have been shown to increase student test scores (Chetty, Friedman and Rockoff, 2014*a*). I test the direct effect of flexible pay on achievement by estimating the following equation:

$$A_{sgt} = \beta \mathbb{1}(t > Exp_{j(s)}) + \gamma X^{s}_{sgt} + \eta Z_{j(s)t} + \sigma_{sg} + \tau_t + \varepsilon_{sgt} \tag{7}$$

where $A_{sgt}$ is the average math or reading test score for students in grade $g$, school $s$, and year $t$. A vector $X^{s}_{sgt}$ of student demographics (such as the share of students who are female, Black, Hispanic, economically disadvantaged, English-language learners, or migrants) allows me to control for differences in student observables across school-grades and over time. The inclusion of school-by-grade fixed effects $\sigma_{sg}$ controls for time-invariant characteristics of the schools that are specific to each grade. In this equation, the parameter $\beta$ captures the change in test scores after the expiration of districts' CBAs relative to before.

Estimates of $\beta$ on the sample of FP districts indicate that reading achievement increased by 0.06 standard deviations in these districts after a CBA expiration (Table 7, top panel, column 1, significant at 1 percent). This estimate is robust to controlling for the demographic makeup of the student body and for districts' budget components and measures of union power (column 2). By comparison, achievement did not significantly change in SP districts (Table 7, top panel, columns 3-4). Columns 5-6 of Table 7 confirm that the difference in the estimates for $\beta$ between FP and SP districts is significant at 10 percent.

Math achievement also increased in FP districts after the expiration of districts' CBAs, although to a smaller (and noisier) extent: the estimate of $\beta$ is equal to 0.05 percent of a standard deviation (Table 7, bottom panel, column 1, significant at 10 percent). Again the difference is indistinguishable from zero in SP districts (Table 7, bottom panel, column 4).[41]

These tests indicate that changes in the composition and effort of teachers in FP districts following the change in pay schemes led to a sizable increase in students' test scores. As a benchmark, the increase in reading scores in FP districts is equivalent to approximately one third of the increase caused by a reduction in class size from 35 to 30 students (0.2 standard deviations Angrist and Lavy, 1999).

[41] Baron (2018) estimates an overall negative effect of Act 10 on student achievement; these estimates, however, do not distinguish between FP and SP districts.

# VII Discussion and Conclusion

This paper has studied the effects of the introduction of flexible pay for public school teachers on the composition of the workforce, teachers' effort, and student achievement. A switch away from seniority-based salary schedules towards pay-for-quality in a subset of Wisconsin school districts resulted in high-quality teachers moving to these FP districts and low-quality teachers either moving to districts which remained with the salary schedules or leaving the public school system altogether. As a result, the composition of the teaching workforce improved in FP districts. Effort exerted by all teachers also increased and, subsequently, test scores improved.

As cross-district movements and exits are rare events, the magnitudes of these compositional changes (and the associated increase in student test scores) were limited in size in Wisconsin over the five years following Act 10. Nevertheless, they could become larger over time as more teachers move and exit each year, especially if the correlation between salaries and teachers' quality and effort becomes stronger with time (for example because districts become better at identifying talented teachers). If, however, SP districts also switch to a FP scheme over time, the long-run effects of a policy change such as Act 10 could differ from the short-term ones. While the sorting of teachers across districts might become less prevalent when flexible pay is offered everywhere, the ultimate impact of this policy on the labor market for teachers and student achievement depends on the effects of flexible pay on the supply of new teachers, the exit of existing teachers, and the effort of all teachers. A thorough investigation of the general-equilibrium effects of flexible pay that captures all these channels represents an important avenue for future research.

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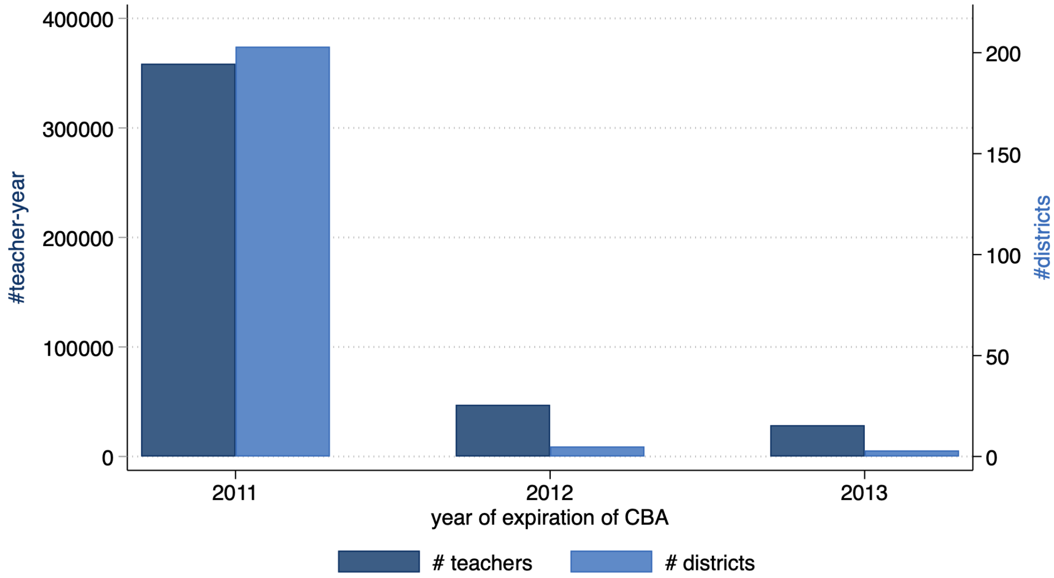
# Figures

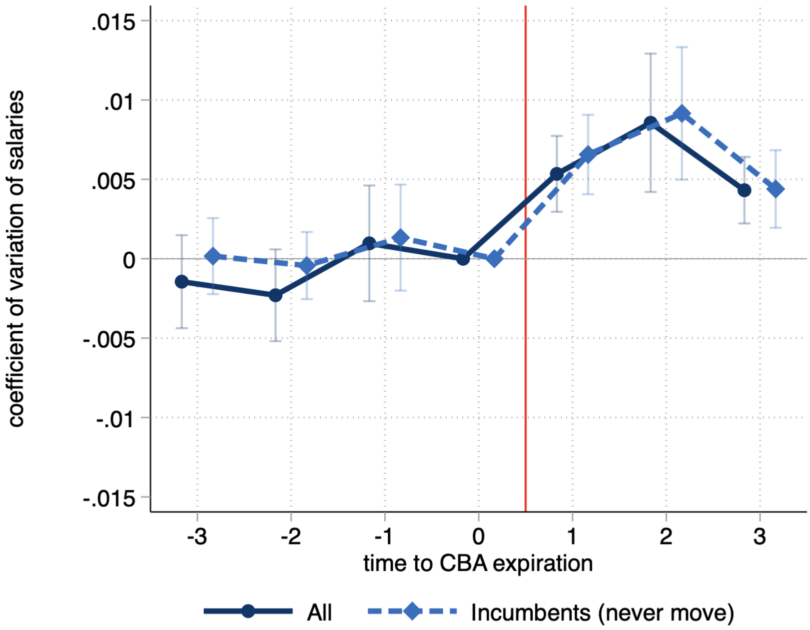
Figure 1: Number of Teachers and Districts, by Year of Expiration of Districts' CBAs



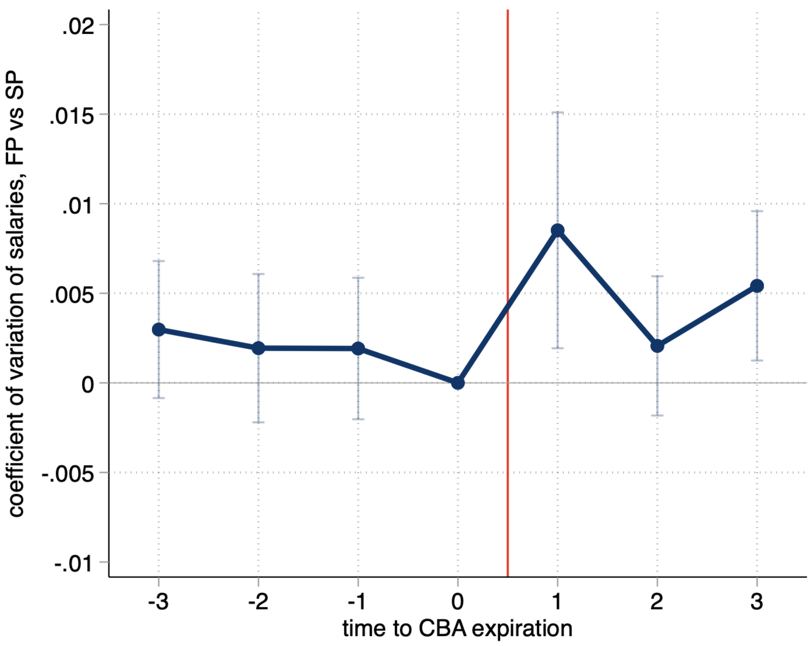

Note: Total number of teacher-year observations (darker bars) and districts (lighter bars), by year of expiration of districts' CBAs.

Figure 2: Coefficient of Variation of Salaries Around a CBA Expiration

Panel A: All districts

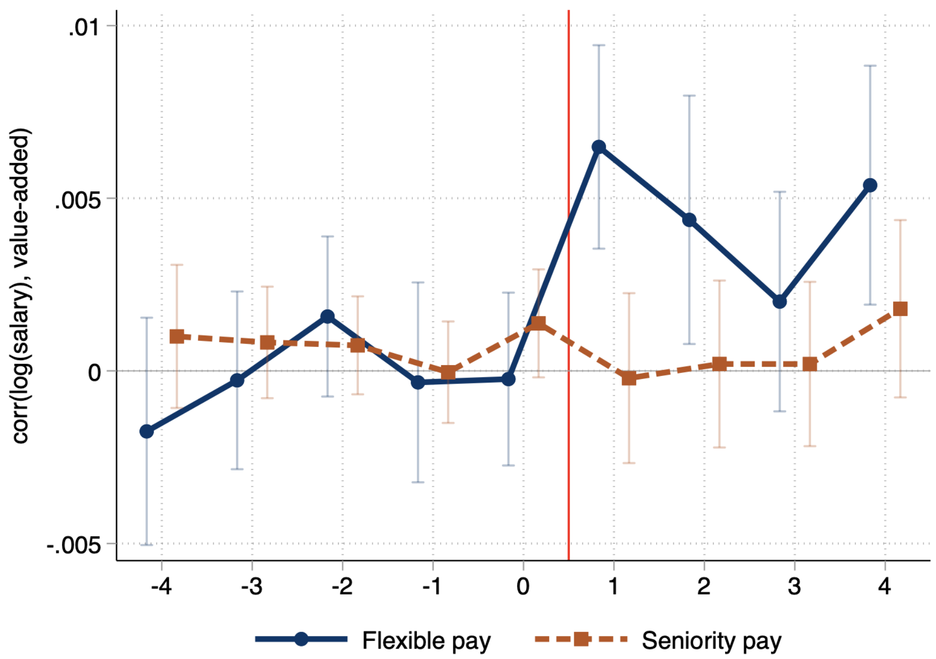



Panel B) FP vs SP districts




*Notes*: Panel A: Point estimates and 90 percent confidence intervals of the parameters $\delta_n$ in the equation $cv_{jt} = \sum_{-3}^{3} \delta_n \mathbb{1}(t - Exp_j = n) + \theta_j + \tau_t + \varepsilon_{jt}$. The variable $cv_{jt}$ is the coefficient of variation of salaries in district $j$ and year $t$, calculated as the ratio between the standard deviation of salary residuals (obtained from a regression of salaries on experience-by-education and district-by-year fixed effects) and average salary. The variable $Exp_j$ is the year of expiration of district $j$'s CBA, and $\theta_j$ and $\tau_t$ are district and year fixed effects, respectively. The coefficient $\delta_0$ is normalized to zero. Panel B: Point estimates and 90 percent confidence intervals of the parameters $\eta_n$ in the equation $cv_{jt} = \sum_{-3}^{3} \eta_n FP_j * \mathbb{1}(t - Exp_j = n)\theta_j + \sum_{-3}^{3} \delta_n \mathbb{1}(t - Exp_j = n) + \theta_j + \tau_t + \varepsilon_{jt}$, where the variable $FP_j$ equals one for FP districts. The coefficient $\eta_0$ is normalized to zero. In both panels observations are weighted by the number of teachers in each district and year; standard errors are clustered at the district level.

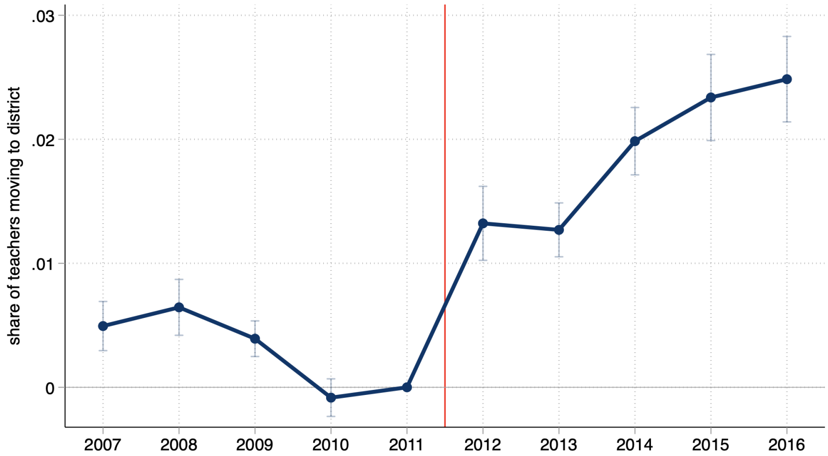
Figure 3: Correlation, Salaries and Value-Added: FP and SP Districts Around A CBA Expiration



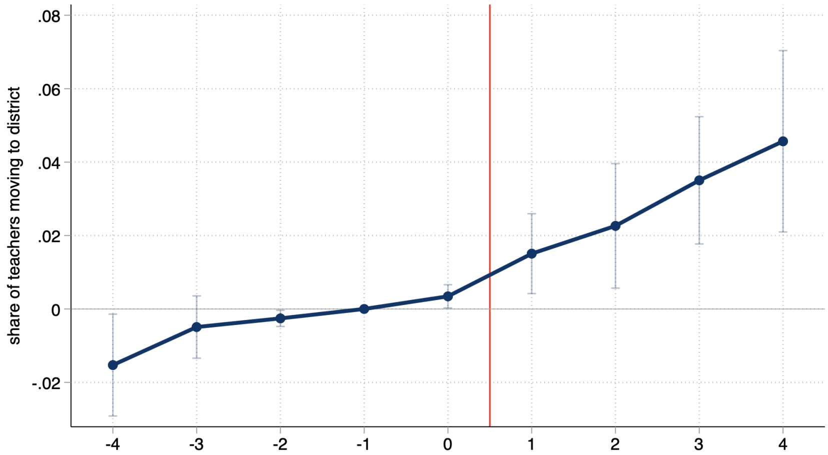

*Notes*: OLS estimates and 90 percent confidence intervals of the coefficients $\delta_s$ in the regression $log(w_{it}) = \sum_{s=-4}^{4} \delta_s VA_{it} * \mathbb{1}(t - Exp_{j(it)} = n) + \beta X_{it}^{w} + \theta_{j(it)t} + \varepsilon_{it}$. The variable $log(w_{it})$ is the natural logarithm of salary for teacher $i$ in year $t$. The variable $VA_{it}$ is teacher VA and the variable $Exp_j$ is the year of expiration of district $j$'s CBA. The vector $X_{it}^{w}$ includes indicators for years of experience interacted with indicators for the highest education degree and with an indicator for years after 2011. The vector $\theta_{jt}$ contains district-by-year fixed effects. The coefficients $\delta_s$ are estimated and shown separately for FP and SP districts. VA is calculated separately for the years the years 2007–2011 and 2012–2016. Bootstrapped standard errors are clustered at the district level.

Figure 4: Moving Rates, by Year (Panel A) and by Time-to-CBA expiration (Panels B and C)

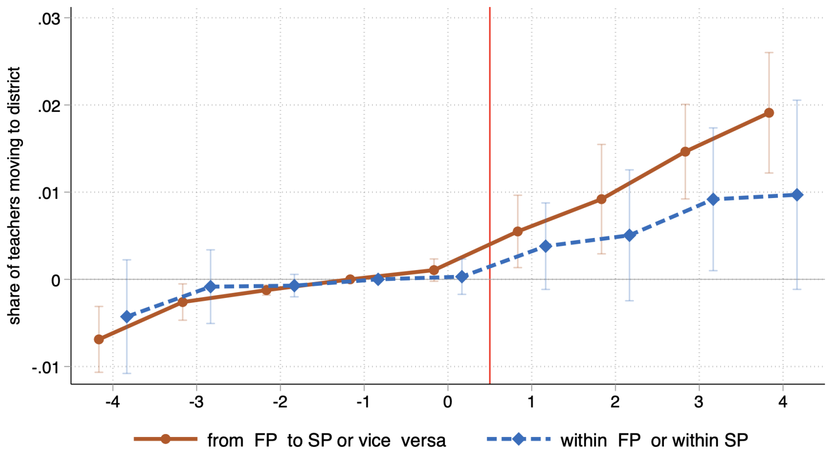
Panel A) By year




Panel B) By time-to-CBA expiration

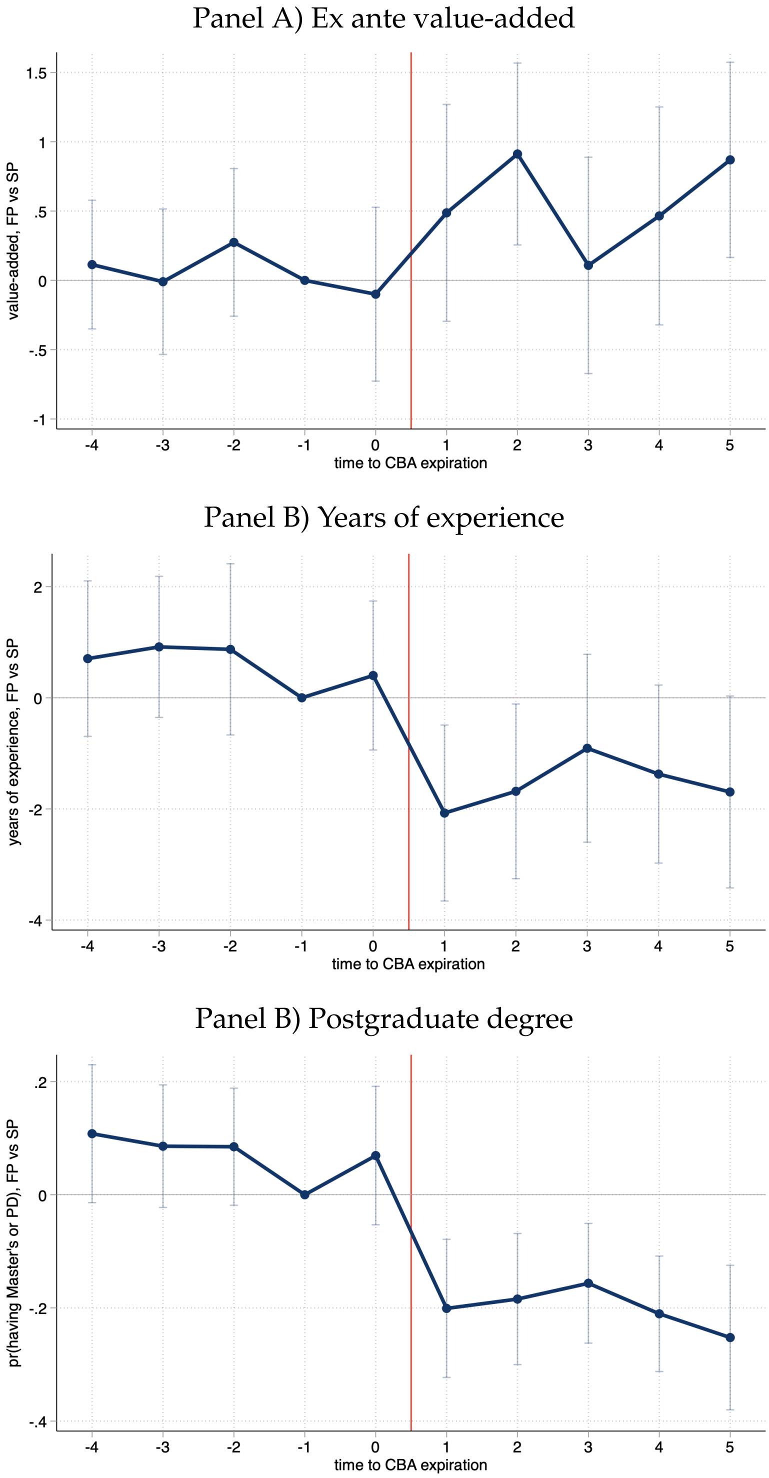



Panel C) By time-to-CBA expiration and district of origin and destination



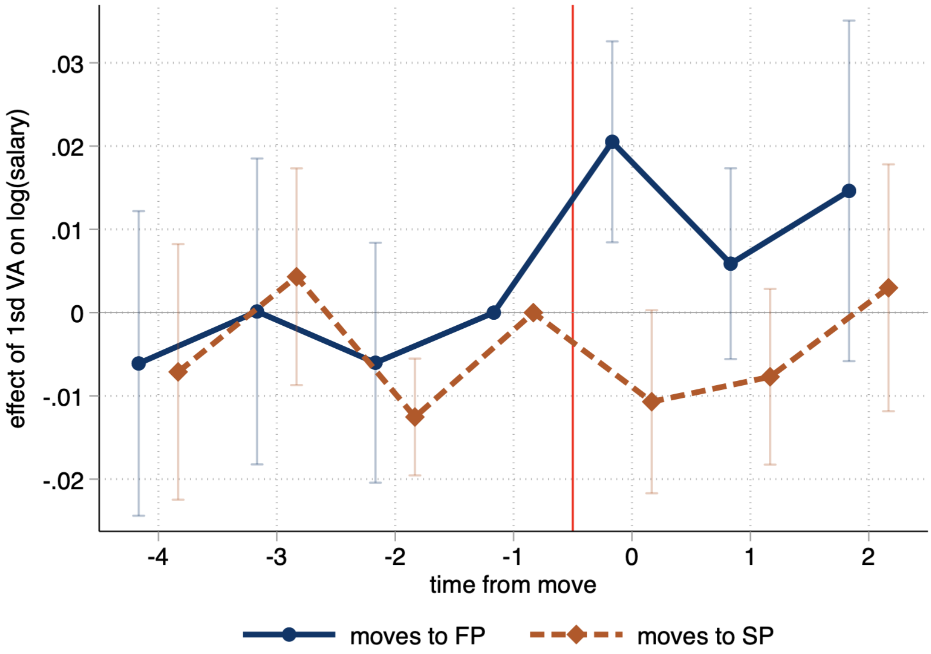

*Notes*: Shares of teachers changing district, by year (panel A) and by time elapsed from the expiration of each district's CBA (panels B and C). In panel A, rates are normalized with respect to 2011; in panels B and C, they are normalized with respect to the year before a CBA expiration, and obtained controlling for year fixed effects. In panel C, moving rates are shown separately for teachers who move from a FP to a SP district or from a SP to a FP district ("from FP to SP or vice versa," solid line) and for teachers who move from a FP to another FP district or from a SP to another SP district ("within FP or within SP," dashed line). Standard errors are clustered at the district level.

Figure 5: Changes in The Characteristics of Movers Around a CBA Expiration




*Notes*: Estimates and 90 percent confidence intervals of $\beta_k$ in the regression $Y_{it} = \alpha FP_{j(it)} + \sum_{-4}^{5} \beta_k FP_{j(it)} \mathbb{1}(t - Exp_{j(it)} = k) + \beta_0 \mathbb{1}(t > Exp_{j(it)}) + \gamma X_{it} + \tau_t + \varepsilon_{it}$, where $Y_i$ is either ex ante VA (panel A), years of experience (panel B), or an indicator for having a postgraduate degree (panel C) for teacher $i$ in year $t$; $Exp_j$ is the year of expiration of district $j$'s CBA; $X_{it}$ includes indicators for the type of district in $t-1$ and $t$, alone and interacted with an indicator for years after 2011; and $\tau_t$ is a vector of year fixed effects. The sample is restricted to teachers who change district in each year. *Ex ante* VA is calculated using test scores for the years 2007–2011. Standard errors are clustered at the district level.

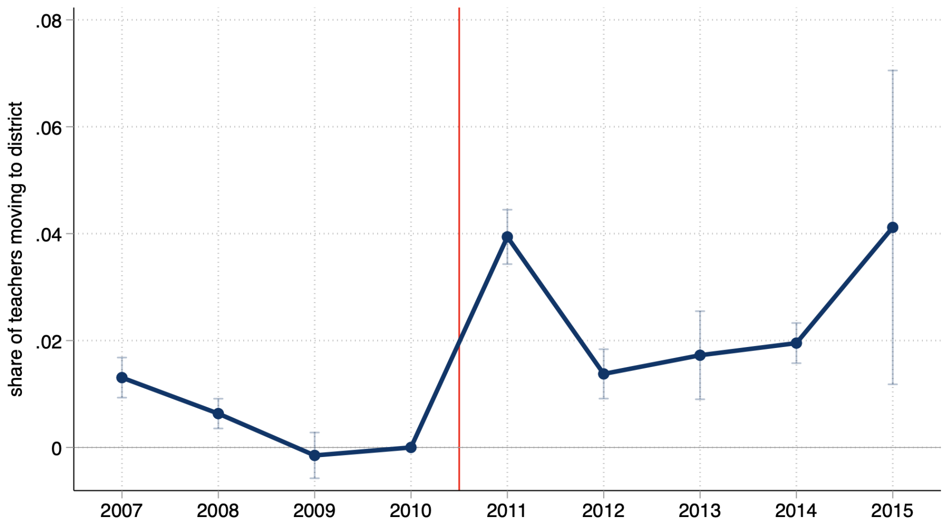
Figure 6: VA and Salaries of Movers Around a Move, FP and SP Districts



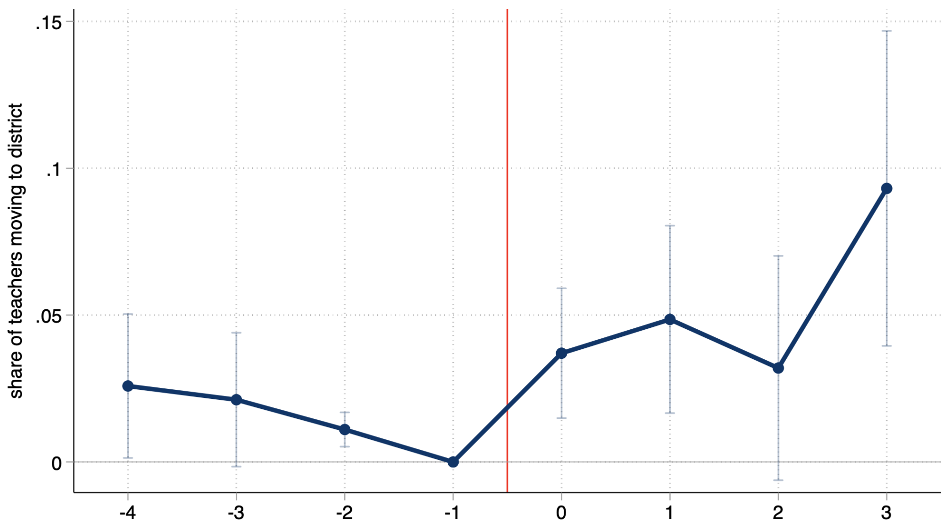

*Notes*: OLS estimates and 90 percent confidence intervals of the coefficients $\beta_k$ in equation (4). The coefficient $\beta_{-1}$ is normalized to zero. The parameters are estimated separately for teachers in FP and in SP districts. Standard errors are clustered at the district level.

Figure 7: Exit Rates, by Year (Panel A) and by Time-to-CBA expiration (Panel B)

Panel A) Exit rates by year



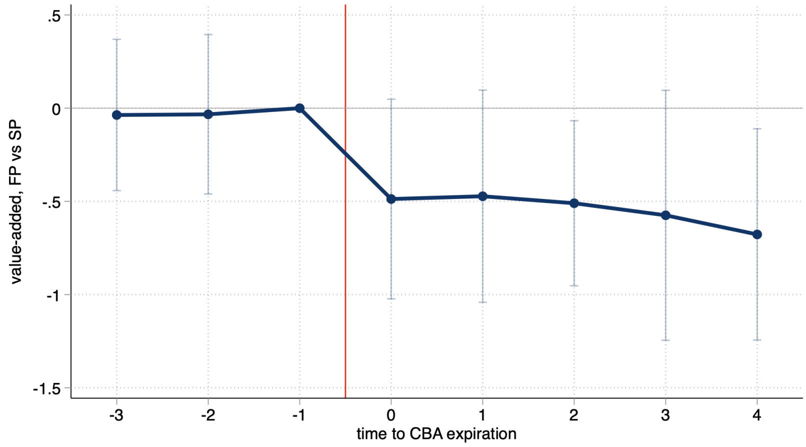

Panel B) Exit rates by time-to-CBA expiration



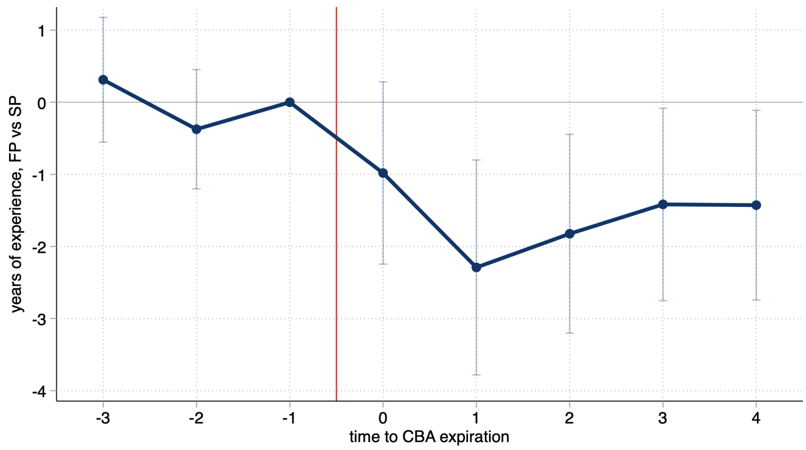

*Notes*: Shares of teachers leaving Wisconsin public schools, by year (panel A) and by time elapsed from the expiration of each district's CBA (panel B). In panel A, rates are normalized with respect to 2010; in panel B, they are normalized with respect to the year before a CBA expiration and obtained controlling for year fixed effects. Standard errors are clustered at the district level.

Figure 8: Changes in The Characteristics of Teachers who Exit Around a CBA Expiration

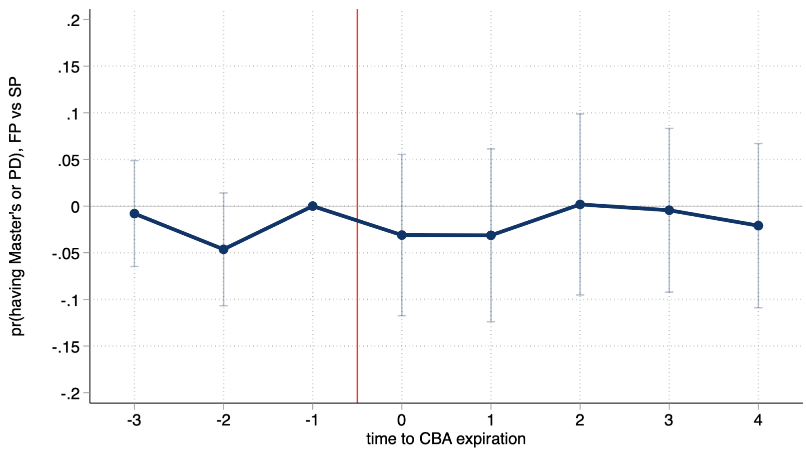
Panel A) Ex ante value-added




Panel B) Years of experience




Panel B) Postgraduate degree

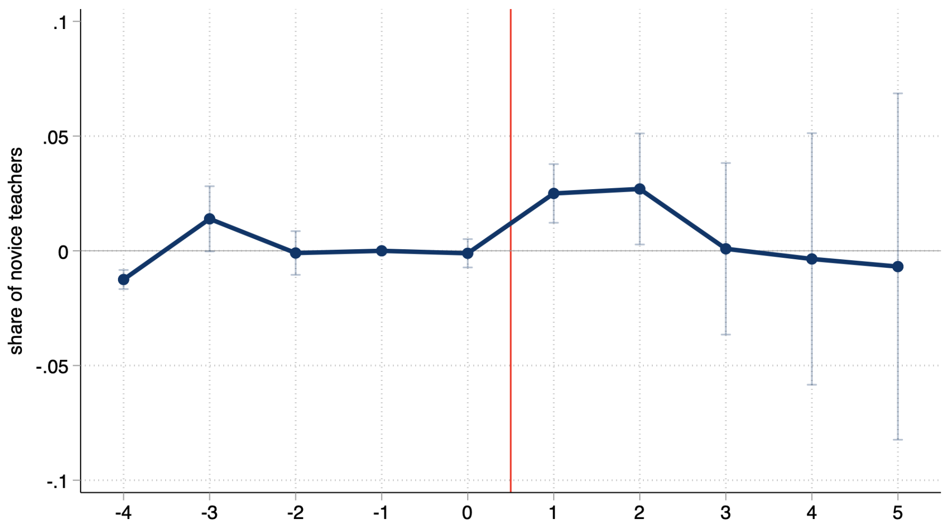



*Notes*: Estimates and 90 percent confidence intervals of $\beta_k$ in the regression $Y_{it} = \alpha FP_{j(it)} + \sum_{-3}^{4} \beta_k FP_{j(it)} \mathbb{1}(t - Exp_{j(it)} = k) + \beta_0 \mathbb{1}(t \geq Exp_{j(it)}) + \gamma X_{it} + \tau_t + \varepsilon_{it}$, where $Y_i$ is either ex ante VA (panel a), years of experience (panel b), or an indicator for having a postgraduate degree (panel c) for teacher $i$ in year $t$; $Exp_j$ is the year of expiration of district $j$'s CBA; and $\tau_t$ is a vector of year fixed effects. The sample is restricted to teachers who exit public schools in each year. In panel A, $X_{it}$ controls for interactions between age, experience, an indicator for having a postgraduate degree, and an indicator for years following 2011; in panel B it controls for interactions between age, an indicator for having a postgraduate degree, and an indicator for years following 2011; and in panel C it controls for interactions between age, experience, and an indicator for years following 2011. The sample is restricted to teachers who leave Wisconsin public schools at the end of each year. *Ex ante* VA is calculated using test scores for the years 2007–2011. Standard errors are clustered at the district level.

Figure 9: Entry Rates, by Year (Panel A) and by Time-to-CBA expiration (Panel B)

Panel A) By year

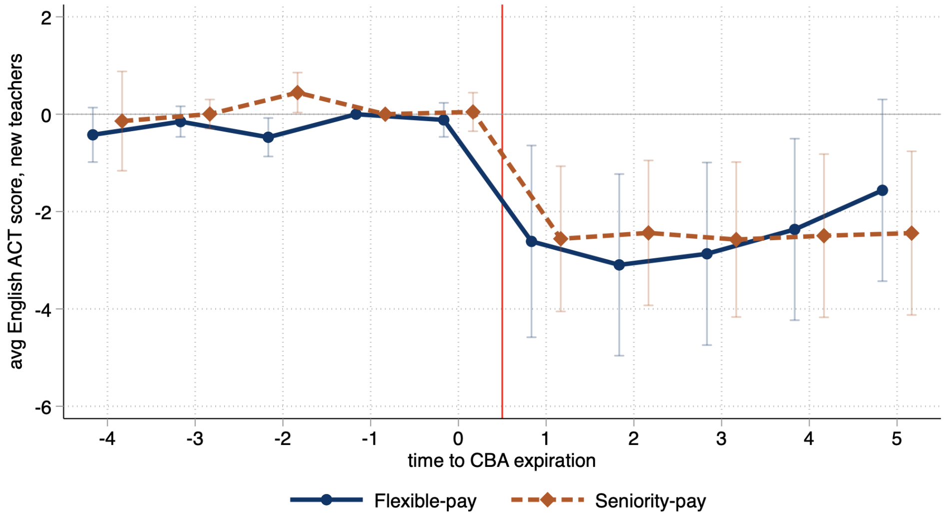

Panel B) By time-to-CBA expiration



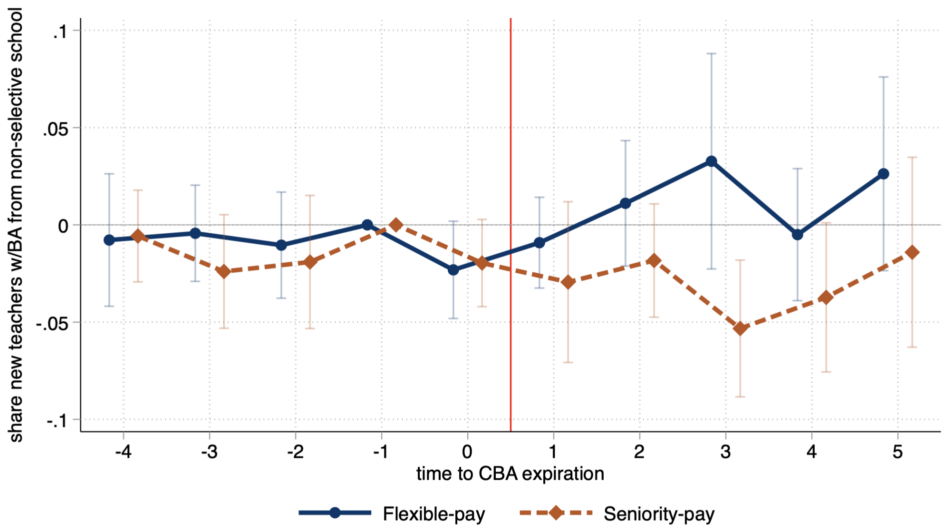

*Notes*: Shares of teachers entering Wisconsin public schools, by year (panel A) and by time elapsed from the expiration of each district's CBA (panel B). In panel A, rates are normalized with respect to 2010; in panel B, they are normalized with respect to the year before a CBA expiration, and obtained controlling for year fixed effects. Standard errors are clustered at the district level.

Figure 10: Changes in The Characteristics of New Teachers Around a CBA Expiration

Panel A) 25th pctile of English ACT score of BA institution

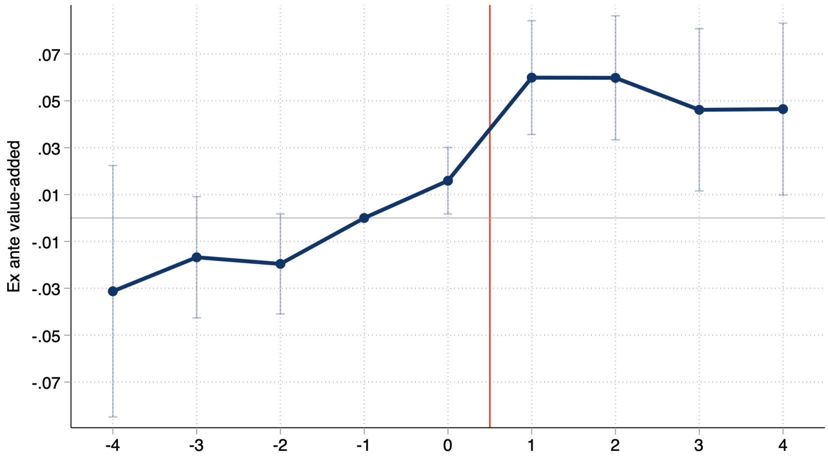



Panel B) Non-selective BA institution



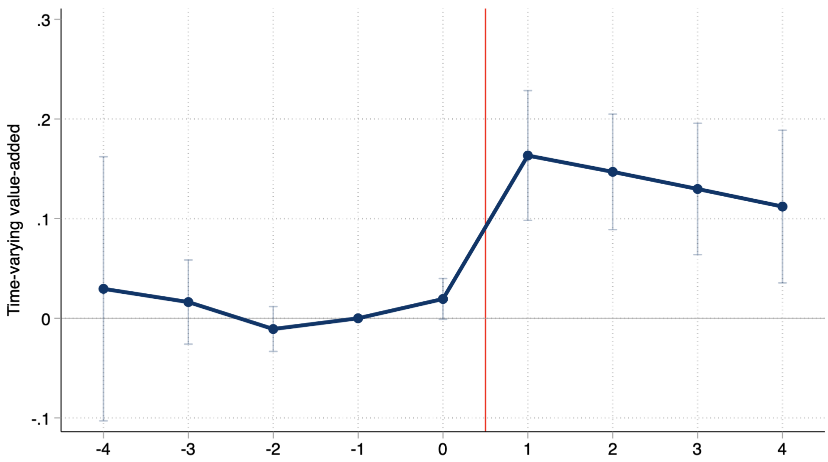

*Notes*: Estimates and 90 percent confidence intervals of $\beta_k$ in the regression $Y_{it} = \alpha FP_{j(it)} + \sum_{-4}^{5} \beta_k FP_{j(it)} \mathbb{1}(t - Exp_{j(it)} = k) + \beta_0 \mathbb{1}(t > Exp_{j(it)}) + \delta Z_{j(it)t} + \tau_t + \varepsilon_{it}$, where $Y_i$ is either the the 25th percentile ACT English score of admitted students in the institution where teacher $i$ obtained her BA (panel A) or an indicator for the BA institution of teacher $i$ being non-selective (i.e., having a zero rejection rate). Both of these variables are measured in 2010. The variable $Exp_j$ is the year of expiration of district $j$'s CBA; $Z_{j(it)t}$ is a vector of district-year-level controls for the level of state aid as a share of total revenues, per-teacher expenditure on salaries, retirement, health, life, and other insurance, and other employee benefits, and indicators for whether the district had a union recertification election in year $t$ and whether the election was successful. The vector $\tau_t$ contains year fixed effects. The sample is restricted to teachers who enter public schools in each year. Standard errors are clustered at the district level.

Figure 11: Changes in the Composition of the Teaching Workforce: Ex Ante Teacher Value-Added Around a CBA Expiration




*Notes*: Point estimates and confidence intervals of the parameters $\beta_k$ in the equation $VA_i = \sum_{-4}^{4} \beta_k FP_{j(it)} * \mathbb{1}(t - Exp_{j(it)} = k) + \gamma X_{it} + \eta Z_{j(it)t} + \theta_{j(it)} + \tau_t + \varepsilon_{ijt}$, where $VA_i$ is ex ante teacher VA, $Exp_j$ is the year of expiration of district $j$'s CBA, the vector $X_{it}$ contains indicators for years of experience and for whether the teacher has a postgraduate degree, the vector $Z_{jt}$ contains interactions between *FP* and indicators for years following 2011, as well as district-year-level controls for the level of state aid as a share of total revenues, per-teacher expenditure on salaries, retirement, health, life, and other insurance, and other employee benefits, and indicators for whether the district had a union recertification election in year $t$ and whether the election was successful. The vectors $\theta_j$ and $\tau_t$ contain district and year fixed effects, respectively. Ex ante VA is calculated using test score data for the years 2007–2011. Standard errors are clustered at the district level.

Figure 12: Changes in Teachers' Effort: Time-Varying Teacher Value-Added Around a CBA Expiration




*Notes*: Point estimates and confidence intervals of the parameters $\beta_k$ in the equation $VA_{it} = \sum_{-4}^{4} \beta_k FP_{j(it)} * \mathbb{1}(t - Exp_{j(it)} = 4) + \gamma X_{it} + \eta Z_{j(it)t} + \theta_{j(it)} + \tau_t + \varepsilon_{ijt}$, where $VA_i$ is teacher VA, allowed to vary before and after 2011; $Exp_j$ is the year of expiration of district $j$'s CBA; the vector $X_{it}$ contains indicators for years of experience and for whether the teacher has a postgraduate degree; the vector $Z_{jt}$ contains interactions between *FP* and indicators for years following 2011, as well as district-year-level controls for the level of state aid as a share of total revenues, per-teacher expenditure on salaries, retirement, health, life, and other insurance, and other employee benefits, and indicators for whether the district had a union recertification election in year $t$ and whether the election was successful. The vectors $\theta_j$ and $\tau_t$ contain district and year fixed effects, respectively. Time-varying VA is calculated separately for each teacher using using test score data for the years 2007–2011 and 2012–2016. Standard errors are clustered at the district level.

## Tables

Table 1: Teacher Salaries and Value-Added. OLS, Dependent Variable is log(Salary)

| | All teachers | | | Middle-school teachers | | |
|---|---|---|---|---|---|---|
| | (1) FP | (2) SP | (3) Diff | (4) FP | (5) SP | (6) Diff |
| VA | -0.000 | 0.001 | 0.001 | -0.002 | 0.001 | 0.001 |
| | (0.001) | (0.001) | (0.001) | (0.002) | (0.001) | (0.001) |
| VA $\times$ post-CBA expiration | 0.004** | -0.000 | -0.000 | 0.007*** | -0.001 | -0.001 |
| | (0.002) | (0.001) | (0.001) | (0.003) | (0.001) | (0.001) |
| VA $\times$ FP | | | -0.001 | | | -0.003 |
| | | | (0.002) | | | (0.002) |
| VA $\times$ FP $\times$ post-CBA expiration | | | 0.004** | | | 0.008** |
| | | | (0.002) | | | (0.003) |
| District $\times$ year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Edu, exp $\times$ post-2011 | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 40142 | 52761 | 92905 | 17592 | 24054 | 41641 |
| # districts | 74 | 90 | 164 | 74 | 90 | 164 |

*Notes*: The dependent variable is the natural logarithm of salaries. The variable *VA* is teacher VA, normalized to have mean 0 and standard deviation 1. The variable *post-CBA expiration* equals 1 for years after the expiration of each district's CBA. All the specifications include district-by-year fixed effects, as well interactions between indicators for years of experience, indicators for the highest education degree, and an indicator for years after 2011. VA is calculated separately for the years 2007–2011 and 2012–2016. Bootstrapped standard errors in parentheses are clustered at the district level. *** $p < .01$, ** $p < .05$, * $p < .1$.

Table 2: Changes in The Characteristics of Movers After a CBA Expiration. OLS, Dependent Variables Are a Teacher's Characteristics

| | Panel A) Dep. var is value-added | | | | | |
|---|---|---|---|---|---|---|
| | Movers to FP | | Movers to SP | | All movers | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| post-CBA expiration | 1.122*** | 0.824*** | -0.111 | -0.158 | 0.039 | 0.044 |
| | (0.155) | (0.225) | (0.152) | (0.203) | (0.144) | (0.158) |
| FP × post-CBA expiration | | | | | 0.941*** | 0.835*** |
| | | | | | (0.166) | (0.183) |

| | Panel B) Dep. var is experience (years) | | | | | |
|---|---|---|---|---|---|---|
| | Movers to FP | | Movers to SP | | All movers | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| post-CBA expiration | -1.637** | -1.762* | -0.724 | -0.693 | -0.778 | -0.718 |
| | (0.811) | (0.886) | (0.701) | (0.834) | (0.610) | (0.598) |
| FP × post-CBA expiration | | | | | -1.293 | -1.604* |
| | | | | | (0.847) | (0.816) |
| Mean of dep. var. | 4.756 | 4.740 | 5.375 | 5.401 | 5.077 | 5.074 |

| | Panel C) Dep. var =1 if teacher has a Master's or PhD | | | | | |
|---|---|---|---|---|---|---|
| | Movers to FP | | Movers to SP | | All movers | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| post-CBA expiration | -0.153** | -0.148* | 0.082** | 0.074* | 0.090*** | 0.092** |
| | (0.059) | (0.081) | (0.037) | (0.042) | (0.031) | (0.038) |
| FP × post-CBA expiration | | | | | -0.247*** | -0.294*** |
| | | | | | (0.049) | (0.070) |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Budget, CB controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Past district | Yes | Yes | Yes | Yes | Yes | Yes |
| FP*post 2011 | No | Yes | No | Yes | No | Yes |
| Mean of dep. var. | 0.313 | 0.327 | 0.316 | 0.330 | 0.315 | 0.329 |
| N | 3298 | 2687 | 3085 | 2402 | 6383 | 5089 |
| # districts | 71 | 69 | 90 | 89 | 161 | 158 |

*Notes*: The dependent variable is *ex ante* teacher VA, expressed in standard deviations (panel A), years of experience (panel B), or an indicator for the teacher having a Master's or a PhD (Panel C). Columns 1-2, 3-4, and 5-6 are estimated on the subsample of movers to a FP district, movers to a SP district, and movers to any district respectively. The variable *FP* equals one for teachers in FP districts. The variable *post-CBA expiration* equals one for years following a CBA expiration. All the specifications include year fixed effects, as well as district-year-level controls for the level of state aid as a share of total revenues, per-teacher expenditure on salaries, retirement, health, life, and other insurance, and other employee benefits, and indicators for whether the district had a union recertification election in year $t$ and whether the election was successful. Columns 2, 4, and 6 also control for the interaction between an indicator for the previous district where the teacher was working being FP and indicators for years before and after a CBA expiration. Columns 5 and 6 control for *FP* and *FP * post 2011*. *Ex ante* VA is calculated using test scores for the years 2007–2011. Standard errors in parentheses are clustered at the district level. *** $p < .01$, ** $p < .05$, * $p < .1$.

Table 3: Changes in The Characteristics of Teachers Who Exit After a CBA Expiration. OLS, Dependent Variables Are a Teacher's Characteristics

| | Panel A) Dep. var is value-added | | | | | |
|---|---|---|---|---|---|---|
| | Exiters from FP | | Exiters from SP | | All exiters | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| post-CBA expiration | -0.524 | -0.506 | 0.263** | 0.297* | 0.087 | 0.160 |
| | (0.689) | (0.446) | (0.115) | (0.171) | (0.121) | (0.167) |
| FP × post-CBA expiration | | | | | -0.584* | -0.514* |
| | | | | | (0.303) | (0.308) |
| | Panel B) Dep. var is experience (years) | | | | | |
| | Exiters from FP | | Exiters from SP | | All exiters | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| post-CBA expiration | -0.625* | -0.441 | 2.310** | 0.454 | 1.954** | 0.857 |
| | (0.372) | (0.735) | (1.144) | (0.564) | (0.970) | (0.697) |
| FP × post-CBA expiration | | | | | -2.116** | -1.977** |
| | | | | | (0.922) | (0.939) |
| Mean of dep. var. | 20.108 | 19.539 | 18.141 | 18.041 | 18.941 | 18.649 |
| | Panel C) Dep. var =1 if teacher has a Master's or PhD | | | | | |
| | Exiters from FP | | Exiters from SP | | All exiters | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| post-CBA expiration | -0.068 | 0.041 | -0.028 | 0.041 | -0.031 | 0.063** |
| | (0.057) | (0.064) | (0.024) | (0.029) | (0.024) | (0.027) |
| FP × post-CBA expiration | | | | | -0.052 | -0.052 |
| | | | | | (0.044) | (0.051) |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Budget, CB controls | No | Yes | No | Yes | No | Yes |
| Teacher controls | Yes | Yes | Yes | Yes | Yes | Yes |
| FP*post 2011 | Yes | Yes | Yes | Yes | Yes | Yes |
| Mean of dep. var. | 0.537 | 0.535 | 0.487 | 0.485 | 0.514 | 0.515 |
| N | 7160 | 5874 | 12099 | 7756 | 21699 | 15635 |
| # districts | 74 | 71 | 90 | 90 | 164 | 161 |

*Notes*: The dependent variable is *ex ante* teacher VA, expressed in standard deviations (panel A), years of experience (panel B), or an indicator for the teacher having a Master's or a PhD (panel C). Columns 1-2, 3-4, and 5-6 are estimated on the subsample of teachers who left FP districts, teachers who left SP districts, and all teachers who left, respectively. The variable *FP* equals one for teachers in FP districts. The variable *post-CBA expiration* equals one for years following a CBA expiration. All the specifications include year fixed effects, as well as district-year-level controls for the level of state aid as a share of total revenues, per-teacher expenditure on salaries, retirement, health, life, and other insurance, and other employee benefits, and indicators for whether the district had a union recertification election in year *t* and whether the election was successful. Columns 5 and 6 control for *FP* and *FP * post 2011*. Panel A controls for interactions between age, experience, an indicator for having a postgraduate degree, and an indicator for years following 2011; panel B controls for interactions between age, an indicator for having a postgraduate degree, and an indicator for years following 2011; and panel C controls for interactions between age, experience, and an indicator for years following 2011. *Ex ante* VA is calculated using test scores for the years 2007–2011. Standard errors in parentheses are clustered at the district level. *** $p < .01$, ** $p < .05$, * $p < .1$.

Table 4: Salaries and Exit. OLS, Dependent Variable is log(Salary)

| | All Districts | FP | SP |
|---|---|---|---|
| | (1) | (2) | (3) |
| Exit | -0.010*** | -0.021*** | -0.004 |
| | (0.003) | (0.006) | (0.005) |
| Exit × post-CBA expiration | -0.003 | -0.000 | -0.002 |
| | (0.005) | (0.010) | (0.005) |
| VA | 0.001 | 0.001 | 0.001 |
| | (0.001) | (0.002) | (0.001) |
| VA × post-CBA expiration | 0.001 | 0.001 | -0.000 |
| | (0.001) | (0.002) | (0.001) |
| VA × Exit | -0.007* | -0.012* | -0.003 |
| | (0.004) | (0.007) | (0.002) |
| VA × Exit × post-CBA expiration | 0.009 | 0.017* | 0.002 |
| | (0.006) | (0.011) | (0.003) |
| District × year FE | Yes | Yes | Yes |
| Edu, exp × post-2011 | Yes | Yes | Yes |
| N | 83750 | 36063 | 47630 |
| # districts | 164 | 74 | 90 |

*Notes*: The dependent variable is the natural logarithm of salaries. The variable *Exit* equals one for teachers exiting from a district at the end of the year. The variable *post-CBA expiration* equals one for years following a CBA expiration (including the year of the expiration). The variable *VA* is teacher VA, normalized to have mean 0 and standard deviation 1. Column 2 is restricted to teachers in FP districts and column 3 is restricted to teachers in SP districts. All the specifications include district-by-year fixed effects, as well interactions between indicators for years of experience, indicators for the highest education degree, and an indicator for years after 2011. VA is calculated separately for the years 2007–2011 and 2012–2016. Bootstrapped standard errors in parentheses are clustered at the district level. *** $p < .01$, ** $p < .05$, * $p < .1$.

Table 5: Changes in the Composition of the Teaching Workforce. OLS, Dependent Variable is Ex Ante Teacher Value-Added

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| FP | -0.028 | | | | |
| | (0.017) | | | | |
| FP × post-CBA expiration | 0.024** | 0.020* | 0.057*** | 0.035*** | 0.040*** |
| | (0.011) | (0.011) | (0.020) | (0.013) | (0.015) |
| post-CBA expiration | -0.021 | 0.001 | -0.001 | 0.015 | 0.014 |
| | (0.022) | (0.018) | (0.018) | (0.011) | (0.012) |
| FP × post-2011 | | | -0.037 | | -0.004 |
| | | | (0.022) | | (0.015) |
| Year FE | Yes | Yes | Yes | Yes | Yes |
| District FE | No | Yes | Yes | Yes | Yes |
| Edu, exp FE | Yes | Yes | Yes | Yes | Yes |
| Budget, CB controls | No | No | No | Yes | Yes |
| N | 89698 | 89698 | 89698 | 70701 | 70701 |
| # districts | 164 | 164 | 164 | 161 | 161 |

*Notes*: The dependent variable is *ex ante* teacher VA. The variable *FP* equals 1 for FP districts. The variable *post-CBA expiration* equals one for years following each district's CBA expiration, and the variable *post-2011* equals one for years following 2011. All the specifications include year, year of experience, and higher education degree fixed effects. Columns 2-5 also include district fixed effects. *CB controls* include an indicator for whether the district had a union recertification election in year $t$ and whether the election was successful. *Budget controls* are district-year-level controls for the level of state aid as a share of total revenues, as well as per-teacher expenditure on salaries, retirement, health, life, and other insurance, and other employee benefits. Ex ante VA is calculated using test score data for the years 2007–2011. Standard errors in parentheses are clustered at the district level. *** $p < .01$, ** $p < .05$, * $p < .1$.

Table 6: Combined Changes in Teacher Composition and Effort. OLS, Dependent Variable is Teacher Value-Added

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| FP | -0.023 | | | | |
| | (0.015) | | | | |
| FP $\times$ post-CBA expiration | 0.078** | 0.076** | 0.091 | 0.089* | 0.085* |
| | (0.036) | (0.036) | (0.063) | (0.045) | (0.050) |
| post-CBA expiration | 0.100 | 0.065 | 0.065 | 0.110*** | 0.031 |
| | (0.075) | (0.055) | (0.057) | (0.033) | (0.046) |
| FP $\times$ post-2011 | | | -0.015 | | |
| | | | (0.074) | | |
| Year FE | Yes | Yes | Yes | Yes | Yes |
| District FE | No | Yes | Yes | Yes | Yes |
| Edu, exp FE | Yes | Yes | Yes | Yes | Yes |
| Budget, CB controls | No | No | No | Yes | Yes |
| Teacher FE | No | No | No | No | Yes |
| N | 94036 | 94036 | 94036 | 74276 | 92167 |
| # districts | 164 | 164 | 164 | 161 | 164 |

*Notes*: The dependent variable is teacher VA, allowed to vary before and after 2011. The variable *FP* equals 1 for FP districts. The variable *post-CBA expiration* equals one for years following each district's CBA expiration, and the variable *post-2011* equals one for years following 2011. All the specifications include year, year of experience, and higher education degree fixed effects. Columns 2-6 include district fixed effects and column 6 controls for teacher fixed effects. *CB controls* include an indicator for whether the district had a union recertification election in year $t$ and whether the election was successful. *Budget controls* are district-year-level controls for the level of state aid as a share of total revenues, as well as per-teacher expenditure on salaries, retirement, health, life, and other insurance, and other employee benefits. VA is calculated separately for the years 2007–2011 and 2012–2016. Standard errors in parentheses are clustered at the district level. *** $p < .01$, ** $p < .05$, * $p < .1$.

Table 7: Student Achievement. OLS, Dependent Variables Are Reading (panel A) and Math Test Scores (panel B)

Panel A) Reading

| | FP | | SP | | Difference | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| post-CBA expiration | 0.0580*** | 0.0401** | 0.0142 | 0.0088 | 0.0142 | 0.0098 |
| | (0.0190) | (0.0155) | (0.0152) | (0.0167) | (0.0151) | (0.0206) |
| FP * post-CBA expiration | | | | | 0.0438* | 0.0360* |
| | | | | | (0.0242) | (0.0217) |
| School × grade FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Dem controls | No | Yes | No | Yes | No | Yes |
| School controls | No | Yes | No | Yes | No | Yes |
| N | 11350 | 8577 | 16909 | 10641 | 28259 | 19218 |
| # districts | 73 | 71 | 89 | 89 | 162 | 160 |

Panel B) Math

| | FP | | SP | | Difference | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| post-CBA expiration | 0.0476*** | 0.0289 | -0.0146 | -0.0142 | -0.0146 | -0.0175 |
| | (0.0172) | (0.0269) | (0.0367) | (0.0387) | (0.0366) | (0.0471) |
| FP * post-CBA expiration | | | | | 0.0622 | 0.0672 |
| | | | | | (0.0404) | (0.0567) |
| School × grade FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Dem controls | No | Yes | No | Yes | No | Yes |
| School controls | No | Yes | No | Yes | No | Yes |
| N | 11350 | 8578 | 16905 | 10636 | 28255 | 19214 |
| # districts | 73 | 71 | 89 | 89 | 162 | 160 |

*Notes*: The dependent variable is average student test scores for Reading and Math, measured at the school-by-grade-by-year level for students in grades 3 to 8. The variable *FP* equals 1 for FP districts. The variable *post-CBA expiration* equals one for years following each district's CBA expiration. All the specifications include school-by-grade and year fixed effects; columns 2, 4, and 6 also include controls for the share of students in each cell who are female, Black, Hispanic, economically disadvantaged, migrants, disabled, or English-language learners, as well as district-level controls such as an indicator for whether the district had a union recertification election in year $t$ and whether the election was successful, the level of state aid as a share of total revenues, per-teacher expenditure on salaries, retirement, health, life, and other insurance, and other employee benefits. Observations are weighted by the number of students in each cell. Standard errors in parentheses are clustered at the district level. *** $p < .01$, ** $p < .05$, * $p < .1$.