Collective Bargaining Laws and Returns to STEM Majors in the Labor Market for Teachers

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January 2022

Abstract:

In light of growing difficulties for schools to attract teachers in science, technology, engineering, and mathematics (STEM) fields and the continued discussions surrounding unionization of education, this paper examines the effect of collective bargaining laws on the salary of teachers with a STEM degree. To identify the effect, we leverage the policy discontinuity of CB laws at state borders and compare the earnings of STEM-degree holding teachers in a cross-border commuting zone. Our results show that the bargaining laws lead to higher returns to STEM degrees in the labor market for female teachers, who predominate the teaching profession. In exploring a potential mechanism, we demonstrate that in states which mandate collective bargaining, female teachers accrue longer durations of experience. Our results are consistent with the literature which shows the role of labor unions in enhancing women's working conditions and pay.

Keywords: Collective bargaining, STEM, teacher pay

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I. Introduction

School districts are facing difficulties to find teachers in science, technology, engineering, and mathematics (STEM) fields (Feng and Sass 2018) as opportunities for better paying jobs outside of teaching make it difficult to recruit and retain teachers with an academic background in those fields. Considering the crucial role that teachers play in the production of student achievement, the under-performance of US students in international math and science tests and the racial achievement gap are attributed to the lack of adequate qualified STEM teachers (National Commission on Mathematics and Science Teaching for the 21st Century 2000; Ingersoll and Perda 2010).[1] Amid the inadequate supply of STEM teachers, the National Academy of Sciences (2007) underscores the need for improving K-12 mathematics and science education to avoid the erosion of the U.S.'s comparative advantage in the global economy. With increasing importance placed on STEM education and teachers' unions being an important stakeholder in K-12 public education, it is important to determine their role in STEM teachers' compensation

Teachers' unions are controversial, and their role in the provision of K-12 education and cognitive achievement production has become a divisive topic. Proponents argue that the unions improve education production via efficient allocation of resources. A large body of research shows that the unions provide higher returns to various aspects of teacher compensation, such as seniority, base wages, and working environment (Cowen and Strunk 2015). Opponents criticize unions for creating barriers to school reforms and stagnating students' performance.[2] Further, unions are drawing attention to their role in reducing gender wage gap (Biasi and Sarsons 2021). Since women are generally averse to engaging in negotiation and less likely to seek or fight for conducive environment for their career progress (Babcock and Laschever 2003), unions can use their bargaining power to provide higher benefits for women. Because female STEM teachers have better outside opportunities than female non-STEM teachers, unions can have a larger impact on the former. However, the question of whether teachers' unions influence STEM teachers' pay remains unanswered.[3]

[1] In the latest 2018 Program for International Student Assessment (PISA) tests, which assesses 15-year-old students, the U.S. ranks 37 in math and 18 in science out of 178 countries and territories participated.
[2] See Cowen and Strunk (2015) for detailed review
[3] For consistency and facilitating the discussion, we define STEM teachers as those who major in STEM fields in their undergraduate degrees.

In this study, we provide the first evidence whether collective bargaining rights affect STEM teachers' earnings. To identify potential STEM teachers, we leverage recently available information on the field of study in the American Community Survey (ACS), covering the period 2009-2018. Identifying the effect of teachers' unions on STEM teachers' pay is challenging as unobserved heterogeneities determine both unionization across states and pay jointly. To isolate the effect of collective bargaining (CB) laws on the earnings of STEM teachers, we exploit the discontinuity in CB rights at state borders within labor markets for teachers. We proximately define the labor market for teachers as a commuting zone (CZ) and limit our analysis to only CZs crossing state boundaries. Teachers in those CZs can be subject to differential CB laws.

Our results provide evidence that CB laws have a significantly positive impact on the annual earnings of STEM teachers. The returns to a STEM major in labor markets for teachers in states that mandate CB is approximately 5.2 percent higher as compared to the return for those in states without the legal mandate. In view of heterogeneous labor markets that men and women face, women's predominance of the teaching profession, and possible differential roles of unions across genders, we examine effects for men and women separately.[4] Our results show that the effects are concentrated on female teachers. Specifically, CB laws increase the annual earnings of female STEM teachers by near 8 percent. For male STEM teachers, the effect is imprecisely estimated.

Further supplementary analyses provide credence to the causal interpretation of our results. First, we employ balancing tests and the results suggest that observable characteristics between CB and non-CB areas within CZs are quite balanced. Second, we control for various characteristics that are considered to be correlated with CB laws, such as political ideology, local amenities, and economies of size, and our estimates remain almost unchanged.

In an attempt to identify a potential mechanism behind our findings, we examine the relationship between CB laws and STEM teachers' experience. We find that CB laws lead to an increase in the duration of experience of female STEM teachers, suggesting that unions support the retention of female STEM teachers. For male teachers, the effect is imprecisely estimated, which is consistent with our baseline finding. Our findings of CB laws becoming helpful in

[4] According to National Center for Education Statistics, around 76.5 percent of teachers are women.

retaining female teachers, but not male teachers are consistent with studies in the literature (e.g., Han 2020).

In being the first paper to examine the relationship between CB rights and pay for STEM teachers, this analysis contributes to broadening our understanding of how union bargaining powers affect school resources. Given the critical role of unions and CB rights in the allocation of educational resources and schooling outcomes, a deeper understanding of their full impacts on labor markets for teachers is warranted to improve education policy. Closest to ours is the literature that examines the impact of teachers' unions on various teachers' compensation. Hoxby (1996) shows that unions positively affect teachers' wages. Frandsen (2016) uses the enactments of CB rights to estimate the effect on public employees' pay and finds little effect on teachers' pay. In contrast, Brunner and Ju (2019) document the positive effect of CB laws on public workers' wages, a finding that is in spirit similar to ours. Rose and Sonstelie (2010) and Brunner and Squires (2013) show that CB rights lead to an increase in the starting salaries of teachers and higher returns to experience. West and Mykerezi (2011) assess the effects of unionization on various aspects of teacher compensation, such as average earnings, the returns to experience, and the returns to graduate degrees. Further, by investigating the differential effects of unions across genders, we contribute to the literature documenting that labor unions play a critical role in reducing the gender wage gap. Biasi and Sarsons (2021) indicate that the expiration of CB rights in Wisconsin increased the gender gap, highlighting that unions are likely associated with narrowing the gap.

Second, our work complements the broader literature examining teacher pay. Regmi (2021) provides new evidence on earnings differences between teachers and non-teachers.[5] Beyond analyses on the pay differences, Player (2009) assesses whether teachers are compensated for their ability, proxied by the selectivity of colleges they attended. The author finds that teachers with a degree from most selective colleges have an earnings premium of 7 to 14 percent.

Third, our analysis regarding the effect of CB laws on the experience of STEM teachers, in terms of career longevity, is connected with the literature examining possible tools to avoid teacher attrition and the literature on the connection between teacher experience and productivity. Using data from Florida, Feng and Sass (2018) provide evidence of both student loan forgiveness and

[5] See Podgursky (2011) for a comprehensive review of earlier findings in this topic.

one-time bonus programs having huge effects in reducing the exit of math and science teachers. Clotfelter et al. (2008) show that an annual bonus of $1,800 reduces the turnover of math, science, and special education teachers by about 17 percent. Hendricks (2014), who examines the connection between teacher pay and experience so as to understand the former's potential role in student achievement, presents evidence of higher wages helping to retain teachers. Harris and Sass (2011) show that the experience of teachers leads to an improvement in student achievement throughout their career, even if the first five years have the largest effects. Similarly, Papay and Kraft (2015) provide further evidence on the continued importance of the teacher experience in improving students' mathematic achievement. Taken together with the teacher experience-productivity literature, the implication of our findings is that if CB laws improve the retention rate of STEM teachers via a high salary, that may help improve education production.

The paper proceeds as follows. Section II explains the data and Section III presents our main empirical strategy and results. We provide robustness checks and a potential mechanism in Section IV. Section V concludes.

II. Data

We assemble data from various sources for our analysis. Our main data come from the 2009-2018 American Community Survey (ACS) extracted from the Integrated Public Use Microdata Series (Ruggles et al. 2019). Two features of the ACS are particularly essential for the context of our research design. First, the ACS began reporting individuals' fields of study in 2009, making it possible to identify potential STEM teachers.[6] We follow the Department of Homeland Security's STEM Designated Degree Program list to classify majors into the list of STEM majors.[7] In cases where there is no perfect mapping from this list to the ACS's list of college majors, we assign majors to the list of STEM majors. We present the complete list of STEM in Table A5. Second, the ACS, sampling one percent of the total U.S. population, provides a discernably larger sample size compared to other household surveys, such as the Current Population Survey.

Using the variable "OCC1990" that uses the 1990 Census Bureau occupational classification scheme, we define teachers as those who report being primary school teachers, secondary school

[6] It is important to note that the ACS reports the field of study that individuals majored in their bachelor's degree.
[7] The link is https://www.ice.gov/sites/default/files/documents/Document/2016/stem-list.pdf.

teachers, and special education teachers. We exclude private school teachers as they are not subject to collective bargaining laws and have different working environments and salary schedules. We also drop teachers who classify themselves into "*kindergarten and earlier school*" and "*teachers not mentioned elsewhere*" from the data.[8] The rationale behind this is that we cannot ascertain whether they are full-time regular school teachers or represent non-school teachers such as private tutors. Additionally, we restrict the sample to ages 25-54, a group of prime-age working people, with a bachelor's degree or beyond since the teaching profession requires at least a four-year college degree.

The ACS provides individuals' annual income, which is their pre-tax salary income received from an employer from the past 12 months. We convert annual incomes to 2009 dollars using the Consumer Price Index (CPI) for All Urban Consumers. We drop workers whose earnings are imputed to prevent our estimates being biased by imputation (see Bollinger and Hirsch 2006 for details regarding biases caused by earnings imputations in household surveys).

We compare the STEM teachers' earnings in a single labor market defined as a commuting zone (CZ). A CZ comprising multiple counties is defined on the basis of journey-to-work data. The most granular level of geographical identification available in the ACS data is the Public Use Microdata Area (PUMA), which comprises a county or cluster of counties. PUMAs' delineations are based on the population data from the most recent decennial census and are updated every 10 years. Out of our sample period, 2009 to 2011 are based on the 2000 Census, and the years afterward on the 2010 Census. We use two different types of crosswalks to allocate PUMAs to CZs. We follow Autor and Dorn (2013) for the 2009-2011 period, and for the 2012-2018 period, we use Autor, Dorn, and Hanson (2019). One issue that needs to be highlighted is that some PUMAs straddle across multiple counties possibly being stratified into different CZs. This leads to a possibility of those PUMAs being mapped into more than one CZ. We allocate these PUMAs to all possible CZs. Hence, individuals from those PUMAs appear multiple times in our sample. We account for multiple reappearances by weighting by the proportional probability of each individual from each PUMA belonging to a given CZ, as in Autor and Dorn (2013). On top of that,

[8] As we will see, we conduct a robustness check including kindergarten and earlier school teachers and our results are similar.

we also apply the sample weight from the ACS throughout our analysis. Table 1 presents summary statistics.

Collective Bargaining Laws. We obtain information on collective bargaining (CB) statutes from Freeman and Valletta (1988). We also verify this dataset from a different source, Sanes and Schmitt (2014), who document the CB rights of all public sector employees. Since federal labor laws exempt public school teachers, state statutes determine public teachers' CB provisions. And, states have introduced diverse legal systems governing CB rights in their scope and nature. Nonetheless, we can broadly classify them into three categories (Lindy 2011): (i) CB "mandatory" states, (ii) CB "permissible" states, and (iii) CB "prohibited" states. In "mandatory" states, school districts have "an obligation to bargain in good faith," when teachers' unions present demands. Acting in a bad faith leads to stiff penalties. A total of 34 states and the District of Columbia are "mandatory" states.[9] In "permissive" states, statutes allow school districts freedom when it comes to involvement in CB. That these states do not have statutes mandating CB has led courts to interpret such an absence of mandatory statutes as an implicit prohibition (Frandsen 2016, Brunner and Ju 2019). In "prohibited" states, state laws explicitly ban school districts from collectively bargaining with unions. We, therefore, categorize states into two groups: those with mandatory CB laws and those that explicitly or implicitly prohibit collective bargaining. Figure 1 shows a map of states that mandate CB for teachers.

III. Empirical Strategy and Results

I. Empirical Strategy

We confront two challenges in identifying the effect of collective bargaining (CB) laws on STEM teachers' salaries. First, decisions on granting CB laws solely fall within states' jurisdiction. As visualized in Figure 1, most states where bargaining is not mandatory are from the south. This underpins the view that mandated and non-mandated states have differential institutional arrangements and labor market conditions, which we cannot observe but affect the STEM teachers' earnings. Another source of omitted variable bias is the availability of local amenities, which likely

[9] These states include AK, CA, CT, DC, DE, FL, HI, ID, IL, IN, IA. KS, ME, MD, MA, MI, MN, MT, NE, NV, NH, NJ, NM, NY, ND, OH, OK, OR, PA, RI, SD, TN, VT, WA, and WI. We drop respondents from TN after 2010 as it repealed its law mandating CB for public school teachers. Likewise, we drop WI after 2011 from our analysis as it passed Act 10 in 2011, which basically ended the CB rights of teachers.

affect public- and private-sect wage differentials (Brueckner and Neumark 2014). This is very much applicable in the context of analyzing the pay gap between teachers and non-teachers since "teacher collective bargaining largely followed the trend of public employee bargaining" (Podgursky 2011).

To overcome these challenges, we exploit the discontinuity in CB legislation at state borders within a single labor market, as defined by a commuting zone (CZ). Since we limit our analysis to CZs extending across states, teachers within CZs can be subject to different collective bargaining laws. With CZs comprised of a cluster of counties, within where people can travel to work, they should resemble similar labor market conditions and underlying amenities. Specifically, we estimate the following regression:

$$\ln(earnings_{icst}) = \alpha + \tau_1 STEM_{icst} + \quad \tau_2 STEM_{icst} * CB_s + X'_{icst}\beta + \delta_{ct} + \gamma_s + \epsilon_{icst}. \quad (1)$$

In this model, $\ln(earnings_{icst})$ represents the annual earnings of individual i in commuting zone c in state s and year t. $STEM$ is a dummy variable for whether one received a degree in a STEM field. Likewise, CB is constructed as an indicator variable that takes the value of one for states where CB_s in mandatory. Note that in this model, we do not need to include a separate indicator variable for CB_s as it is subsumed by state fixed effects (γ_s). δ_{ct} is a vector of CZ-by-year fixed effects, which eliminate confounding factors that change year-over-year within CZs. Using this term allows us to identify the effect of CB laws within a CZ where teachers, due to them being in different states, are subject to different CB rights. Likewise, we use individual controls, represented by X, to improve the precision of our parameter of interest. They include marital status, race, gender, and the number of children.[10] We also include the number of children since teachers tend to have the higher number of children than non-teachers.[11] Our analysis is limited to public school teachers.

[10] Marital status is an indicator variable for whether an individual is married or not. We divide race into four groups: non-Hispanic white, Hispanic, non-Hispanic black, and other non-Hispanic races. Education is divided into a bachelor's degree, a master's degree, a professional degree, and a doctorate degree.

[11] We would like to note that we do not use age and education as controls as they are probably endogenous. Given that we include individuals with a bachelor's degree in the age range of 25-54 years, age is a proxy for experience. The past literature has documented that unions affect the returns to experience and an advanced degree. Therefore, we rather consider experience and an advanced degree as potential mechanisms through which CB laws operate to affect the earnings of STEM teachers.

The identifying assumption of this model is that unobserved heterogeneities within a CZ that determine both earnings and the adoption of CB laws affect both STEM teachers and non-STEM teachers in a similar way. We cluster standard errors at the state level as unobserved components in determining wages within a state are probably correlated.

II. Balancing Tests

In order to demonstrate that our preferred specification has a causal interpretation, we perform a series of balancing tests for state-specific commuting zone characteristics. Specifically, we estimate the models of the following form:

$$C_{cst} = \alpha + \tau_1 CB_s + \delta_{ct} + \epsilon_{cst} \quad (2)$$

where C_{cst} denotes demographic characteristics of commuting zone c in state s and year t, which include the vote share of the Democratic Party in a presidential election, population density, the median household income, the unemployment rate, the labor force participation rate, and the employment-population ratio.[12] We also execute similar estimations for individual characteristics constructed from the 2009-2018 ACS. The characteristics include age, female, education (an undergraduate degree or an advanced degree), married, race (white, black, Hispanic, and other race), and the number of children. The coefficient of primary interest τ_1 represents an average difference in characteristics between areas with and without mandatory CB laws within a commuting zone. Having a statistically insignificant estimate of τ_1 can be interpreted as CB regime being uncorrelated with a within-commuting-zone characteristic.

Panel A of Table 2 presents the balancing test results for state-specific CZ characteristics, while Panel B reports balancing test results for observable individual characteristics from the ACS. Note that the estimates reported in Column 1 utilize all the variations across commuting zones. The results suggest that there exist significant differences in the characteristics of CZs located in CB-mandatory and non-mandatory states. For example, CZs located in CB-mandatory states have a

[12] We obtain data on the vote share from MIT Election Data & Science Lab (https://electionlab.mit.edu/data). We collect data on the median household income from the Census Bureau (https://www.census.gov/topics/income-poverty/income/data/tables.2009.html) and county-level labor force statistics from the Bureau of Labor Statistics (https://www.bls.gov/lau/#cntyaa). We aggregate them to the commuting zone level by weighting by county population.

significantly higher median household income, a higher labor force participation rate, and contain types of voters who are more likely to support the Democratic presidential candidate. This finding is not surprising given the self-selection of states into mandating bargaining laws as shown in Figure 1.

Column 2 of Table 2 presents results from balancing tests that utilize only identifying variation used in our analysis. Specifically, we restrict the sample to CZs that cross state borders and include commuting zone-by-year fixed effects to equation (3). Hence τ_1 is now identified from CZs that cross state borders with different bargaining environments on either side of the border. All coefficients within a CZ comparison are statistically insignificant, except white, which is marginally significant at the 10 percent level. This provides reassurance that CZ characteristics are balanced across mandatory and non-mandatory areas. Overall, these analyses provide strong evidence in support of our research design, giving the causal interpretation of the results based on Equation (2).

III. Likelihood of Becoming Teachers

With STEM teachers being instrumental in K-12 educational production, it is of policy relevance to assess how (un)attractive the teaching profession is for STEM-degree holders. This analysis also provides an essential and meaningful context for understanding and interpreting our main results. Therefore, before we present our baseline results, we first estimate the likelihood of individuals with a STEM degree becoming teachers. We estimate the following model:

$$Teacher_{icst} = \alpha + \tau_1 STEM_{icst} + X'_{icst}\beta + \delta_{ct} + \gamma_s + \epsilon_{icst}, \quad (3)$$

where all variables are defined as above. The analysis uses public school teachers and non-teachers, where non-teachers are limited to individuals aged 24-54, employed with a bachelor's degree or above. We also want to note that we exclude self-employed, unpaid family workers, and those in the armed forces. We present the results in Table A1.

The first column contains estimates for the full sample, the second column for women, and the third column for men. Having a STEM degree reduces the likelihood of becoming a teacher by around 7 percent. The effect is still stronger for women, with STEM-degree holders being approximately 9 percent less likely to become teachers. For STEM-degree-holding men, the probability of becoming teachers declines by around 5 percent. Our findings highlight why school

districts are finding it increasingly difficult to recruit STEM teachers. Importantly, the results are in line with the prediction of Hoxby and Leigh (2004) who illustrate that the compressed wage structure brings larger returns to low-skilled individuals but smaller returns to skilled workers, pushing highly qualified women out from teaching. This also leads to the lack of adequate qualified teachers in STEM fields (Podgursky and Springer 2011).

IV. Main Results

In this section, we present the results of regressions, based on Equation (1), estimating the impact of CB laws on the teachers' earnings. All models are weighted using the person weight provided by the ACS and the probability of an individual belonging to a particular CZ as defined above. Furthermore, all the specifications reported in Table 3 and subsequent tables include a full set of individual characteristics, the state fixed effects, and the commuting zone-by-year fixed effects.

Columns 1 and 2 of Table 3 report the results for the full sample. The estimated coefficients of STEM indicate that teachers in STEM fields experience about $100 \times (e^{-0.071} - 1) = -6.9\%$ pay penalty.[13] However, the positive and statistically significant coefficient on the interaction between STEM and CB suggests that the gap is significantly reduced for those covered by collective bargaining. Specifically, we find that, as shown by the coefficient on the interaction between STEM and CB laws (*CB*STEM*), STEM teachers in mandatory states are paid about 8% higher than STEM teachers in non-mandatory states. These results are qualitatively consistent with Hoxby (1996) who finds that public school teachers in states with CB rights earn approximately 5 percent more than otherwise similar teachers in states without CB rights.

Columns 3-6 of Table 3 show results for male and female teachers, separately. This stratification is of great interest, as both groups have different experiences and opportunities in the labor market. Furthermore, women have been predominant in the profession, with 76 percent of public school teachers being women in the school year 2017-18, according to the National Center for Education Statistics. For this reason, we analyze the effects for both groups separately throughout the remainder of our analysis. As shown in columns 3 and 4, there is clear evidence that female STEM teachers not covered by collective bargaining face a larger pay penalty than

[13] Since the dependent variable is measured in logs, we convert the coefficient on a dummy variable in this way throughout the analysis.

those who benefit from collective bargaining. In terms of magnitude, our results suggest that mandatory CB laws are associated with an approximately 7.7 percent wage premium for female teachers in the STEM field. Interestingly, such a premium associated with CB does not remain significant for male teachers. The estimated coefficient on the *STEM*CB* for men presented in Columns 5 and 6 is small and negative, and it is not statistically different from zero.

Overall, these findings suggest the substantial heterogeneous effects of CB across teacher genders and highlight that female teachers benefit the most from the right to bargaining collectively for earnings. These results are consistent with the findings in the literature. For example, Cahen (2019) argues that a lack of collective bargaining legislation leads to individualized labor contracts. In such an environment, women are more likely to be subjected to wage discrimination. Our results also support the findings by Han (2020) which suggests that teachers' union power is associated with a reduced gender pay gap.

IV. Robustness Checks and Mechanism

I. Robustness Checks

Despite our research design that allowed us to uncover compelling evidence on the effect of CB laws on STEM teachers, it is still possible, though of less concern, that unobservable factors are driving our results. Therefore, we conduct robustness checks to provide further support against the role of confounding factors or other alternative explanations.

Including All CZs. Though our research design to compare the earnings of STEM-teachers at state borders is transparent and appealing, one possibility is that paying our attention to only cross-bordering CZs may throw away some identifying variation. Therefore, we re-estimate Equation (1), including all CZs. Table 4 presents the results. The magnitudes of the coefficients are almost identical, while their precision increases slightly.

Local amenities. Brueckner and Neumark (2014) reckon that localities having strong amenities help public workers to increase their rent-extraction ability leading to a larger relative pay to public sector workers. Their empirical findings show that public workers in states permitting collective bargaining accrue a higher wage premium. The connection between amenities and public workers' wages operates through the channel that the higher desire of potential residents to live in high-amenity areas and their larger willingness to pay for that purpose provide better opportunities for

rent-extraction. This improves the influence of unionized public sector workers through increased opportunities for campaign contributions and for organizations. Likewise, studies regarding teachers' decisions with regards to locations suggest that teachers prefer to be located and teach in high-income areas. To address a possible concern that high amenities are likely correlated with both the enactment of CB laws and teachers' earnings, we expand our main model by controlling for the median household income interaction with CB.[14] Table 5 contains the results. Columns 1 and 2 present the results for women and men. Controlling for the median household income yields qualitatively similar results. Additionally, we use three additional amenity variables following Brueckner and Neumark (2014), which are mild temperate, dry weather, and coastal proximity.[15] As before, we interact each variable with CB and include them as additional controls. The results are qualitatively similar.

Economies of size. Another potential issue that can compound our findings arises from economies of size associated with population density (Duncombe and Yinger 2007). Economies of size characterizes that spending per pupil decreases with an increase in the number of pupils. For example, in rural areas, a considerable portion of schooling resources may go towards transportation costs, which means a lower amount of spending available for teachers. The fixed costs of administrators such as board of directors and on physical capital such as labs and buildings decline with a rise in students. Considering that more densely populated states are more likely to have CB laws, it is a possibility that our results may be picking up such a mechanical relationship. Therefore, we run our main model controlling for population density's interaction with CB. As reported in Columns 5 and 6 of Table 5, the coefficients are very similar to baseline estimates.

Political Leaning. Given the fact that the Democratic Party is more supportive of organized labor (Rose and Sonstelie 2010), the composition of voters can influence the collective bargaining process. Using data from Pennsylvania, Babcock and Engberg (1999) show that the return to years of experience is much larger in areas where residents have affirmative views about unions. We expand our baseline specification to include the interaction between the Democratic party's vote shares in presidential elections and CB. As shown in Columns 7 and 8 in Table 5, our results are robust to this inclusion.

[14] We aggregate the income data to the commuting zone level by weighting by county population.
[15] We obtain these data from Brunner and Ju (2019).

Using Non-Teachers as a Control Group. To further check the robustness of our findings, we use non-teachers as an additional control group. Using a new source of variation coming from the comparison between STEM teachers and non-teacher private sector workers helps to wash away any unobservable confounders that affect both teachers and non-teachers within a CZ in a similar fashion. We use the following regression:

$$\ln(earnings_{icst}) = \alpha + \tau_1 T_{icst} + \tau_2 STEM_{icst} + \tau_3 T_{icst} * STEM_{icst} + \tau_4 T_{icst} * CB_s + \tau_5 STEM_{icst} * CB_s + \tau_6 T_{icst} * STEM_{icst} * CB_s + X'_{icst}\beta + \delta_{ct} + \gamma_s + \epsilon_{icst}. \quad (4)$$

In this model, T is an indicator variable that takes the value of one for public-school teachers, zero otherwise. Other terms are defined as above. τ_6, the coefficient on the interaction term *T *STEM*CB,* captures the effect of CB laws on STEM teachers. This coefficient can be interpreted as the difference in the earnings of STEM-teachers between CB-mandatory and CB-non-mandatory areas, compared to the difference in earnings between STEM-teachers and non-teachers. Columns 1 and 2 of Table A3 present the results for men and women separately. STEM teachers in mandatory states are paid about 8.3% higher than otherwise similar STEM teachers in non-mandatory states. Overall, this exercise further strengthens our baseline estimates.

II. Using an Alternative Measure: Union Density

In an alternative but direct measure of union power, we use the union density of teachers. This exercise also connects this study to the literature using union density to measure the influence of unions on various outcomes. In order to calculate union density across states, we use the basic monthly Current Population Survey (CPS) data from 2009 to 2018 (Flood et al. 2020). We define the density as the number of teachers who report that they are covered by unions in a year in a state by the total number of teachers in the year in the state. We estimate the model of the form:

$$\ln(earnings_{icst}) = \alpha + \tau_1 STEM_{icst} + \tau_2 Union_{st} + \tau_3 STEM_{icst} * Union_{st} + X'_{icst}\beta + \delta_{ct} + \gamma_s + \epsilon_{icst}. \quad (5)$$

In this model, $Union_{st}$ represents union density in state s year t. All other variables are defined as above. We find evidence that school unionization improves STEM teachers' earnings (Table 6).

III. Mechanism

Having established that collective bargaining (CB) laws have robust, consistent effects on STEM teachers' pay, in this subsection we explore a possible mechanism behind our findings. One

argument in favor of teachers' unions is that they improve the working environment for teachers, making the teaching profession more attractive. This view raises the possibility that CB power has potential to retain STEM teachers.

STEM teachers' career choice can be viewed in the framework of neoclassical models, particularly on-the-job search, which postulate that workers strive to maximize their expected lifetime utility. In that framework, a higher wage increases the opportunity cost of outside job options net of search cost (Burdett 1978). Using panel data from Texas, Hendricks (2014) shows that higher pay to teachers increases their retention. Likewise, relative non-pecuniary benefits in teaching become an important determining factor for teachers' quits (Goldhaber, Gross, and Player 2011). Using data from Wisconsin, Goldhaber, Gross, and Player (2011) provide suggestive evidence that female teachers consider their future wages when making their exit decisions. Collectively, these studies suggest that CB laws improve working conditions and future earnings prospects with the unions rewarding experience, which makes leaving a teaching career for outside opportunities more costly. Therefore, we investigate whether STEM teachers in "mandatory" states have a longer duration of experience, which results in higher pay. To do so, we estimate Equation (1) replacing the dependent variable with implied experience. As the ACS data do not provide a direct measure of experience, we calculate experience as the maximum of age minus years of schooling minus six and zero, i.e., $experience = \max\{0, age - years\ of\ schooling - 6\}$.

Table 7 contains the results. We find that CB laws significantly increase female teachers' duration of the experience. Female teachers in "mandatory" states tend to have an additional 1.14 years of experience as compared to those in "non-mandatory" states. We find a positive effect for male teachers as well, but the magnitude is extremely small and the estimate is imprecisely estimated. In line with both the theoretical predictions and empirical findings in the literature, our results indicate that improved working conditions arising from teachers' unions could be more effective in retaining female STEM teachers. For example, Han (2020) provides evidence of unions leading to a decline in their attrition.

Further, previous studies document that unions bargain for larger returns to advanced degrees (e.g., West and Mykerezi 2011). It is a possibility that STEM-degree holders with an advanced degree may find teaching more attractive. Therefore, we examine whether CB laws increase the pool of STEM teachers with an advanced degree. Table A4 provides the results: Column 1 for

female teachers and Column 2 for male teachers. We find no evidence of CB laws having any effect on a STEM-degree holder's likelihood of having an advanced degree.

We like to emphasize that there could be other explanations why CB raises the STEM teachers' earnings but due to the data paucity, we cannot explore additional mechanisms here. One notable possibility is that CB laws help female teachers, whose negotiating power and culture over salary could otherwise be weaker, to maintain competitive salaries (Biasi and Sarsons 2021). When more data are available, future research can explore different mechanisms. Related to it, one obvious extension of our analysis is linking the STEM teacher pay to student achievement. Though there is substantial literature on the link between both relative wages of teachers and experience and schooling outcomes, it is unclear whether paying higher wages to STEM teachers lead to better outcomes for students.

V. Conclusion

Over decades, teacher unionization has remained at the center of policy discussions regarding the provision of K-12 education. Due to their prominent role and scope in influencing educational policies, emerging literature has strived to provide evidence that teachers' unions' rent-seeking behavior has enhanced various aspects of teacher compensation, such as the return to experience and base salary. However, the literature does not offer any evidence on the potential role that unions can play in the earnings of STEM teachers. Understanding the role of unions in STEM teachers' pay is crucial to improving educational policies. This is especially true considering that school districts find hiring teachers in STEM fields an increasingly difficult task since STEM teachers have more lucrative non-teaching options than non-STEM teachers. Further, improving STEM education is gaining prominence in policy debates.

In this paper, we provide the first investigation of the relationship between collective bargaining laws and STEM teachers' pay. We document robust evidence that in states where collective bargaining is mandatory, female STEM teachers have around 8.5 percent higher earnings. Our results on male STEM teachers are imprecisely estimated. In exploring a potential mechanism, we show that CB laws significantly increase the duration of experience of female STEM teachers. This suggests their potential role in retaining STEM teachers, a challenge that school districts have been experiencing. Future research constitutes investigating whether a higher pay for STEM teachers translates into better student outcomes.

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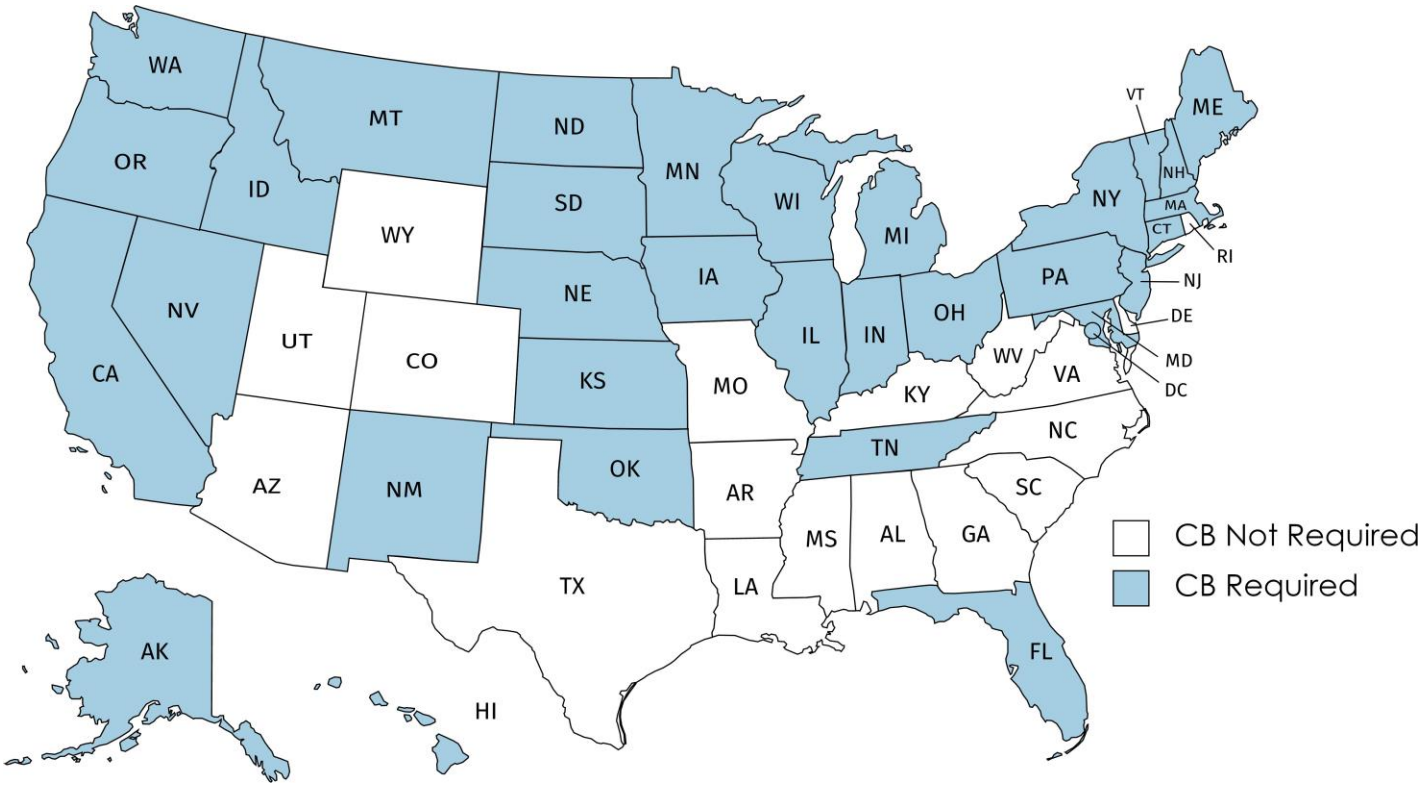
Figure 1: Collective Bargaining Laws Across States



Notes: The figure visualizes collecting bargaining (CB) laws across states. States where CB is mandatory are shaded. See the text for details.

Table 1: Summary Statistics

	Women				Men			
	CB		No CB		CB		No CB	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Log Hourly Wage	3.187	0.659	3.088	0.641	3.421	0.726	3.38	0.713
Log Annual Wage	10.689	0.875	10.606	0.857	11.079	0.86	11.063	0.825
Teacher	0.125	0.33	0.17	0.375	0.046	0.21	0.051	0.22
STEM	0.167	0.373	0.155	0.362	0.36	0.48	0.359	0.48
Bachelor's Degree	0.643	0.479	0.636	0.481	0.661	0.473	0.662	0.473
Advanced Degree	0.357	0.479	0.364	0.481	0.339	0.473	0.338	0.473
Age	38.373	8.606	38.381	8.545	39.064	8.51	39.138	8.452
Married	0.608	0.488	0.636	0.481	0.661	0.473	0.7	0.458
White	0.69	0.463	0.75	0.433	0.693	0.461	0.764	0.425
Hispanic	0.085	0.278	0.055	0.228	0.079	0.269	0.055	0.227
Black	0.068	0.252	0.11	0.313	0.053	0.224	0.075	0.263
Other Race	0.158	0.364	0.084	0.278	0.176	0.381	0.106	0.308
No of Children	0.939	1.085	0.988	1.089	1.012	1.173	1.084	1.196
N	353,250		163,938		312,864		141,012	

Notes: We provide summary statistics using the American Community Survey (ACS) data from 2009 to 2018. We report summary statistics for collective bargaining (CB) mandatory and non-mandatory areas separately by gender. The first four columns include the sample of women and the last four the sample of men. We apply the weight as described in the text to calculate these statistics.

Table 2: Balancing Test

Dependent Variables	**Overall Comparison**	**Within CZ Comparison**
Panel A: CZ Level Aggregated Characteristics		
Median Household Income	5,502.733***	-1,610.15
	-630.747	-1,736.16
Population Density	97.538	84.553
	-60.317	-139.097
Democratic Presidential Candidate's Vote Share	0.047***	0.035
	-0.009	-0.023
Unemployment Rate	-0.874***	0.392
	-0.136	-0.291
Employment-to-Population Ratio	0.046***	-0.006
	-0.004	-0.01
Labor Force Participation Rate	4.542***	-0.434
	-0.395	-1.001
N	8,740	2,820
Panel B: Individual Characteristics		
Age	-0.185*	-0.157
	(0.096)	(0.184)
Female	-0.002	0.009
	(0.006)	(0.010)
Bachelor's Degree	-0.008	0.001
	(0.008)	(0.018)
Advanced Degree	0.008	-0.001
	(0.008)	(0.018)
Married	-0.030***	-0.029
	(0.01)	(0.025)
White	-0.009	-0.037*
	(0.026)	(0.019)
Black	-0.035***	0.036
	(0.008)	(0.030)
Hispanic	-0.002	0.000
	(0.011)	(0.003)
Other Race	0.046***	0.002
	(0.017)	(0.015)
No. of Children	-0.047*	-0.036
	(0.026)	(0.048)
N	3,359,929	971,064
CZ×Year FEs	N	Y

Notes: Dependent variables are a vector of CZ characteristics. Each cell presents estimates from a separate regression based on Equation (3). Column 1 presents the results estimated making an overall comparison between areas with or without mandatory CB laws. Column 2 contains the results that use CZ-by-year FEs, which allow us to compare characteristics in CB and non-CB areas within a CZ. Standard errors are clustered at the CZ level. * denotes significance at the ten percent level, ** denotes at the five percent level, and *** denotes at the one percent level.

Table 3: Effects on Returns to STEM Teachers: Cross-Border CZs

	Full Sample		Women		Men	
	(1)	(2)	(3)	(4)	(5)	(6)
STEM*CB	0.051**	0.050**	0.077**	0.076**	-0.009	-0.005
	(0.02)	(0.021)	(0.034)	(-0.034)	(0.026)	(0.023)
STEM	-0.071***	-0.066***	-0.117***	-0.112***	0.016	0.019
	(0.015)	(0.015)	(0.025)	(0.025)	(0.018)	(0.014)
N	118,825	118,825	89,909	89,909	28,904	28,904
Indiv. Controls	N	Y	N	Y	N	Y
CZ×Year FEs	Y	Y	Y	Y	Y	Y
State FES	Y	Y	Y	Y	Y	Y

Notes: Dependent variable is the annual earnings. We use Equation (1) to calculate estimates. Standard errors are clustered at the state level. * denotes significance at the ten percent level, ** denotes at the five percent level, and *** denotes at the one percent level.

Table 4: Effects of CB Laws on Returns to STEM Teachers

	Women	Men	Women	Men
	(1)	(2)	(3)	(4)
STEM*CB	0.075***	0.074***	-0.003	0.005
	(0.021)	(0.021)	(0.018)	(0.016)
STEM	-0.106***	-0.102***	-0.005	-0.01
	(0.015)	(0.014)	(0.016)	(0.013)
N	333,072	333,072	105,199	105,199
Indiv. controls	N	Y	N	Y
CZ×Year FEs Y	Y	Y	Y	Y
State FEs	Y	Y	Y	Y

Notes: Dependent variable is the annual earnings. We use Equation (1) to calculate estimates. Standard errors are clustered at the state level. * denotes significance at the ten percent level, ** denotes at the five percent level, and *** denotes at the one percent level.

Table 5: Controlling for Local Amenities

	Women	Men	Women	Men	Women	Men	Women	Men
STEM*CB	0.0759**	-0.0047	0.0759**	-0.0043	0.0758**	-0.0046	0.0759**	-0.0047
	(0.0342)	(0.0228)	(0.0342)	(0.0228)	(0.0342)	(0.0228)	(0.0342)	(0.0227)
STEM	-0.1116	0.0189	-0.1117***	0.0185	-0.1116***	0.0188	-0.1116***	0.019
	(0.0246)	(0.0136)	(0.0246)	(0.0137)	(0.0246)	(0.0136)	(0.0247)	(0.0136)
N	89,909	28,904	89,909	28,904	89,909	28,904	89,909	28,904
Indiv. Controls	Y	Y	Y	Y	Y	Y	Y	Y
CZ×Year FEs	Y	Y	Y	Y	Y	Y	Y	Y
State FES	Y	Y	Y	Y	Y	Y	Y	Y

Notes: Dependent variable is the annual earnings. We use Equation (1) to calculate estimates. Columns 1 and 2 present the results controlling for household income, Columns 3 and 4 for mild temperate, dry weather, and for coastal proximity, Columns 5 and 6 for population density, and Columns 7 and 8 for political ideology. Standard errors are clustered at the state level. * denotes significance at the ten percent level, ** denotes at the five percent level, and *** denotes at the one percent level.

Table 6: Alternative Measure: Union Density

	Women	Men
STEM*Union	0.135*	0.101*
	(0.071)	(0.06)
STEM	-0.149***	-0.057
	(0.049)	(0.041)
Union	-0.024	-0.261**
	(0.093)	(0.111)
N	89,909	28,904
Indiv. Controls	Y	Y
CZ×Year FEs	Y	Y
State FES	Y	Y

Notes: Dependent variable is the annual earnings. We use Equation (5) to calculate estimates. Standard errors are clustered at the state level. * denotes significance at the ten percent level, ** denotes at the five percent level, and *** denotes at the one percent level.

Table 7: Potential Mechanism: Experience

	Women	Men
STEM*CB	1.138**	0.271
	(0.444)	-0.661
STEM	-0.844**	-0.313
	(0.400)	(0.543)
N	89,909	28,904
Indiv. Controls	Y	Y
CZ×Year FEs	Y	Y
State FES	Y	Y

Notes: Dependent variable is experience. We use the specification based on Equation (1) to calculate estimates. Standard errors are clustered at the state level. * denotes significance at the ten percent level, ** denotes at the five percent level, and *** denotes at the one percent level.

Appendix

CPS Data

In order to calculate union density across states, we use the basic monthly Current Population Survey (CPS) data from 2009 to 2018. The CPS which is representative of the whole population in the U.S. is a primary source of labor market statistics such as employment, unemployment, and labor force participation. We classify individuals into being covered by unions if they report that they are either “member of labor union” or “covered by union but not a member.” We restrict the sample to the employed (who report being “at work, or with job but not at work last week”). We apply the weight using the variable “EARNWT” which is a personal-level weight.

Table A1: **Likelihood of STEM-Degree Holders Being Teachers**

	Full Sample	Women	Men
STEM	-0.063***	-0.088***	-0.048***
	(0.003)	(0.005)	(0.002)
N	3,286,448	1,761,307	1,525,141
Indiv. Controls	Y	Y	Y
CZ×Year FEs	Y	Y	Y
State FES	Y	Y	Y

Notes: Dependent variable is an indicator for whether an individual is a teacher or not. STEM is a dummy variable that takes the value of one if an individual holds a STEM degree. We use a linear probability model. Standard errors are clustered at the state level. *denotes significance at the ten percent level, ** denotes at the five percent level, and *** denotes at the one percent level.

Table A2: Including Kindergarten and Earlier School Teachers

	Women	Men
STEM*CB	0.070*	-0.011
	(0.039)	(0.023)
STEM	-0.093***	0.027**
	(0.028)	(0.013)
N	94,611	29,050
Indiv. Controls	Y	Y
CZ×Year FEs	Y	Y
State FES	Y	Y

Notes: Dependent variable is the annual earnings. The estimates are based on Equation (1). In this analysis, we also include kindergarten and earlier school teachers. Standard errors are clustered at the state level. * denotes significance at the ten percent level, ** denotes at the five percent level, and *** denotes at the one percent level.

Table A3: Using Non-Teachers as the Control Group

	Women	Men
Teacher*CB*STEM	0.080*	-0.004
	(0.042)	(0.036)
Teacher*CB	0.070*	0.094**
	(0.040)	(0.042)
Teacher*STEM	-0.367***	-0.186***
	(0.029)	(0.026)
STEM*CB	-0.013	-0.000
	(0.018)	(0.015)
Teacher	-0.030	-0.321***
	(0.036)	(0.034)
STEM	0.254***	0.213***
	(0.011)	(0.011)
N	507,652	442,328
Indiv. Controls	Y	Y
CZ×Year FEs	Y	Y
State FES	Y	Y

Notes: Dependent variable is the annual earnings. We use the specification based on Equation (3). Standard errors are clustered at the state level. * denotes significance at the ten percent level, ** denotes at the five percent level, and *** denotes at the one percent level.

Table A4: Potential Mechanism: Advanced Degree

	Women	Men
STEM*CB	-0.008	-0.064
	(0.023)	(0.038)
STEM	0.033	0.110***
	(0.020)	(0.028)
N	89,909	28,904
Indiv. Controls	Y	Y
CZ×Year FEs	Y	Y
State FES	Y	Y

Notes: Dependent variable is whether a public school teacher has an advanced degree. Standard errors are clustered at the state level. * denotes significance at the ten percent level, ** denotes at the five percent level, and *** denotes at the one percent level.

Table A5: STEM Degree Codes in the ACS Data

ACS Code	College Major	ACS Code	College Major
1103	Animal Sciences	2599	Miscellaneous Engineering Technologies
1104	Food Science	3600	Biology
1105	Plant Science and Agronomy	3601	Biochemical Sciences
1106	Soil Science	3602	Botany
1301	Environmental Science	3603	Molecular Biology
1302	Forestry	3604	Ecology
1401	Architecture	3605	Genetics
2001	Communication Technologies	3606	Microbiology
2100	Computer and Information Systems	3607	Pharmacology
2101	Computer Programming and Data Processing	3608	Physiology
2102	Computer Science	3609	Zoology
2105	Information Sciences	3611	Neuroscience
2106	Computer Information Management and Science		
2107	Computer Networking Telecommunications	3699	Miscellaneous Biology
2401	Aerospace Engineering	3700	Mathematics
2402	Biological Engineering	3701	Applied Mathematics
2403	Architectural Engineering	3702	Statistics and Decision Science
2404	Biomedical Engineering	3801	Military Technologies
2405	Chemical Engineering	4002	Nutrition Sciences
2406	Civil Engineering	4003	Neuroscience
2407	Computer Engineering	4005	Mathematics and Computer Science
2408	Electrical Engineering	4006	Cognitive Science and Biopsychology
2409	Engineering Mechanics, Physics, and Science	4008	Multi-disciplinary or General Science
2410	Environmental Engineering	5001	Astronomy and Astrophysics
2411	Geological and Geophysical Engineering	5002	Atmospheric Sciences and Meteorology
2412	Industrial and Manufacturing Engineering	5003	Chemistry
2413	Materials Engineering and Materials Science	5004	Geology and Earth Science
2414	Mechanical Engineering	5005	Geosciences
2415	Metallurgical Engineering	5006	Oceanography
2416	Mining and Mineral Engineering	5007	Physics
2417	Naval Architecture and Marine Engineering	5008	Materials Science
2418	Nuclear Engineering	5098	Multi-disciplinary or General Science
2419	Petroleum Engineering	5102	Nuclear, Industrial Radiology and Biology
2499	Miscellaneous Engineering	5206	Social Psychology
2500	Engineering Technologies	5701	Electrical and Mechanic Repairs and Technology
2501	Engineering and Industrial Management		
2502	Electrical Engineering Technology	6202	Actuarial Science

2503	Industrial Production Technologies	6108	Pharmacy, Pharmaceutical Sciences
2504	Mechanical Engineering Related Technology	6218	Management Information Systems and Statistics