Staying Put: Positive Spillovers on Teacher Retention from a Middle School Science Initiative

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Abstract

Teacher shortages, especially in high-need subjects and schools, are a long-standing issue in many districts, and teacher attrition is a key driver. In this paper, we examine the association between a professional development-focused science initiative and middle school science teacher retention in the nation's largest school district, NYC. We use detailed teacher-level administrative personnel data on 19 cohorts of teachers from NYC and UA program participation data and estimate likelihood of attrition using a discrete-time hazard model. UA teachers are roughly 3.8 percentage points less likely than similarly situated non-UA teachers to leave their school the following year. This study contributes to the limited evidence on how professional development-focused programs can promote teacher retention in hard-to-staff subjects and schools.

Keywords: science teacher education, middle grades teacher education, recruitment and retention, professional development, urban teacher education

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Teacher shortages, especially in high-need subjects and schools, are a long-standing issue in many districts (Guarino *et al.*, 2004; Ingersoll, 2003; Marinell & Coca, 2013; Nguyen & Redding, 2018). Although recruiting new teachers is important, evidence suggests that teacher attrition is a key driver of the need for teachers (Ingersoll, 2001; Ingersoll & Perda, 2010; Loeb & Beteille, 2008; Sutcher *et al.*, 2019). A recent estimate suggests 90% of the nationwide annual demand for teachers is created when teachers leave the profession, and two-thirds of teachers leave for reasons other than retirement (Carver-Thomas & Darling-Hammond, 2017). This may be particularly true for hard-to-staff subjects and schools, such as math and science, and schools with high portions of students experiencing poverty. Of note, STEM teachers are more likely to turnover than their peers in other subjects, and the odds of leaving are 51% higher for middle school teachers than for elementary school teachers (Nguyen *et al.*, 2020). Therefore, districts might consider policies that improve teacher retention (in addition to efforts to recruit new teachers).

The harmful effects of teacher turnover are well-documented: it increases the number of inexperienced teachers in schools, reduces student achievement, disturbs school-community relationships, and increases school costs (Adnot *et al.*, 2016; Atteberry *et al.*, 2017, Hanushek *et al.*, 2016; Ronfeldt *et al.*, 2013; Sorensen & Ladd, 2020; Watlington *et al.*, 2010). Professional development and related teacher and school characteristics—greater personal career satisfaction and effectiveness, enhanced teacher collaboration, and improved student performance—are all associated with reduced teacher turnover (Nguyen *et al.*, 2020). However, few studies examine the relationship between professional development and teacher retention. Urban districts are especially burdened with high teacher turnover—particularly teacher mobility across schools within the district (Atteberry *et al.*, 2017; Clotfelter *et al.*, 2011; Lankford *et al.*, 2002; Sorensen & Ladd, 2020; Perda, 2013).

In this paper, we examine the association between a professional development-focused science initiative and middle school science teacher retention in the nation's largest school district, New York City (NYC). Our goal is to test the hypothesis that, all else equal, science teachers who participate in NYC's Urban Advantage (UA) program are less likely to leave their school or the district than their non-UA counterparts. UA is a science initiative designed to improve students' understanding of the process of scientific inquiry through high-quality teacher professional development and ancillary support, first implemented in the 2004-05 (2005) school year. Over half of NYC middle schools have participated in the program. Between 2005 and 2021 UA served over 1,900 unique teachers, over 1,400 of whom were still teaching in NYC Department of Education schools in 2021 (over 800 of these teachers actively participated in UA in 2021). While the main goal of the UA program is to improve student science learning, this paper investigates an additional potential benefit of UA—the possible spillover benefits of the program on teacher retention, given the importance of professional development on teachers' career decisions.

To understand the association between UA participation and the likelihood that science teachers leave their school or the NYC Department of Education (NYC DOE), we use variation in teachers' first year in the program and estimate a discrete-time hazard model that accounts for unobserved heterogeneity among teachers and schools that select into the program. We use detailed teacher-level administrative personnel data on 19 cohorts of teachers from the NYC DOE and UA program participation data. Results suggest that UA teachers are roughly 3.8 percentage points less likely than non-UA teachers to leave their school in the following academic year. This study presents empirical evidence on the link between the UA program and improved teacher retention, both within schools and the NYC school district, and contributes to the limited evidence on how professional development-focused programs can promote teacher retention in hard-to-staff subjects and schools.

The Urban Advantage Program

UA launched in September 2004 to bring together the resources of NYC's informal science education institutions (ISEIs) and NYC public schools to improve instruction in middle school science. These institutions include the American Museum of Natural History (lead institution), Brooklyn Botanic Garden, New York Botanical Garden, New York Hall of Science, Queens Botanical Garden, Staten Island Zoological Society, the Wildlife Conservation Society's Bronx Zoo, and New York Aquarium. UA provides teachers and students in NYC Grades 6–8 the opportunity to engage in authentic science practice through professional development for teachers, classroom materials, administrator support, outreach to families, and access to cultural institutions. Over the past 18 years, UA has grown and become embedded in NYC's approach to science instruction, including a recent expansion into elementary schools. The professional development model UA uses provides intense, ongoing, and authentic hands-on learning experiences for teachers. Professional development takes place at participating ISEIs and is conducted by informal science educators from the host institutions and experienced UA teachers.

UA is designed to meet the needs of both novice and experienced teachers. During their first year in UA, teachers attend up to 40 hours of professional learning focused on science and engineering practice and the science-rich cultural institutions themselves. As part of their training, UA teachers work to incorporate the Next Generation Science Standards (standards that engage students in practices of science), conduct their own science learning, and work on long-term projects with other teachers that promote scientific inquiry. This framework is consistent with the teacher-as-learner model of professional development, which has proven effective for teachers in science, technology, engineering, and math (STEM) education (Loucks-Horsley & Matsumoto, 1999). Teachers who continue to participate after the first year complete up to 22.5 hours of professional learning that targets teachers' capacity to effectively integrate science and engineering practices into their instruction. Teachers also receive training on a variety of classroom tools developed by UA staff intended to support them as they develop teaching practices informed by Next Generation Science Standards (NGSS). In the third year and beyond, teachers can receive up to 12.5 hours of continuing professional learning annually; teachers can continue in the program for up to seven years total. The highest levels of professional learning culminate in offerings on reflective practice, in which teachers analyze student work or videos of their own teaching.

The program provides additional teacher- and school-level support beyond professional development. Teachers receive science materials and equipment to use in their classrooms. School administrators can participate in breakfast meetings to network with other administrators at schools in the program to learn ways to improve UA implementation at their school. Moreover, UA teachers, administrators, students, and families receive vouchers for free admission to any of the ISEIs, and schools receive transportation funds to facilitate these trips.

Participation in UA is voluntary. In its first year, UA accepted teachers into the program on a first-come, first-serve basis. Thereafter, interested teachers and schools had to apply to participate in the program. Schools that had more than one science teacher interested in participating, among other criteria, had the highest chance of participating (that is, a school may have one science teacher participate but it is more likely they have two or more science teachers participate). Our estimation strategy attempts to account for this selection bias by limiting the main analysis sample to schools that ever participate in UA and controlling for unobserved differences among teachers that might affect their employment decisions.

During the COVID-19 pandemic, UA professional development, student, and family activities took place virtually. While these activities had traditionally been in-person, UA program staff were able to draw upon the expertise of their colleagues at the ISEIs who had already taught and/or designed online programs and courses. Supplies for professional development sessions were shipped to teachers' homes and activities that might have previously taken place at the ISEIs were redesigned to take place in teachers' own neighborhoods. Attendance rates for the UA program in Spring 2020 were comparable to attendance rates in prior years, and in feedback UA teachers noted how quickly and efficiently moved the program online. In addition, the UA program became a model for teachers to think about how to improve their own online instruction. UA teachers reported the program provided a critical opportunity for them to see and check-in on each other, creating a sense of community they might have otherwise lacked during the early months of the pandemic (Hammerness *et al.*, 2021).

In the 2021-22 school year, the total cost of UA was $6.5 million. It served approximately 1,000 teachers: 900 middle school teachers and 100 elementary school teachers (a pilot to expand the program to elementary schools began in 2016), meaning UA costs approximately $6,500 per teacher.

Literature Review: Teacher Turnover

The Scope of the Problem

There is a lack of detailed, timely, and nationally representative data on the K-12 education labor market in the United States (Bleiberg & Kraft, 2022; Nguyen *et al.*, 2022).

However, district- and state-specific research typically finds that there are significant differences in teacher turnover and attrition by grade level, subject, urbanicity, and school characteristics such as average student performance. Middle schools have particularly high attrition rates nationally (Nguyen *et al.*, 2020) and in NYC: a quarter of teachers leave their schools within one year of entering the workforce, and more than one-half leave within the first three years (Marinell & Coca, 2013). In addition, there is evidence it is especially difficult to recruit and retain science teachers (Guarino *et al.*, 2004; Ingersoll, 2003; Marinell & Coca, 2013; Nguyen *et al.*, 2020; Nguyen *et al.*, 2022; Nguyen & Redding, 2018). Therefore, the UA program, which targets middle school science teachers, is serving a population with particularly high attrition rates.

Despite a public narrative that the COVID-19 pandemic has led to increased teacher attrition, this is not uniformly reflected in the available data. Most research has found that in the first year of the pandemic, teacher retention was stable or increased (that is, teachers who worked in the 2020 school year were equally or more likely to return in 2021 compared to retention rates from years prior to the pandemic) but turnover then increased in 2021 and/or 2022, though it differs across geographic contexts (Bacher-Hicks *et al.*, 2022; Bastian & Fuller, 2022; Camp *et al.*, 2023; Goldhaber & Theobald, 2022). Teachers continue to report increased rates of burnout and intentions to leave the profession (Jotkoff, 2022; Zamarro *et al.*, 2021).

Existing estimates suggest the cost of teacher turnover is high. In 2004, the United Federation of Teachers estimated that the cost of a first-year NYC teacher leaving the district was $13,200. More recent estimates from other districts or national data suggest the cost of replacing a teacher who leaves ranges from $18,000-$21,000 (Barnes *et al.*, 2007; Carroll, 2007; Carver-Thomas & Darling-Hammond, 2017; DeFeo *et al.*, 2017). In addition to the direct financial burden that turnover imposes on schools and districts in terms of recruitment, teacher turnover imposes indirect costs through adverse effects on student performance and the exacerbation of turnover in future years (Sorensen & Ladd, 2020).

How Urban Advantage Might Affect Teacher Turnover

We rely on the conceptual framework advanced by Nguyen *et al.* (2020) to understand how the Urban Advantage program might affect teacher turnover. They categorize correlates of teacher turnover into three groups: external/policy factors, such as teacher evaluation policies, salaries, and union presence; school factors, such as administrative support, professional development, and student achievement; and personal factors, such as career satisfaction and content specialty. Their conceptual framework recognizes the interplay of these three categories in contributing to decisions to leave a school or district (or the profession entirely). In our review of the literature, we focus on the correlates that might be affected by the Urban Advantage program and therefore explain how UA could affect retention. For example, as with many professions, turnover may be affected by job location (e.g. Reininger, 2012) and compensation (e.g. Feng & Sass, 2018). However, the UA program does not affect teacher's base salary or their school location, and so will not affect teacher turnover through these mechanisms. Figure 1 presents a modified version of Nguyen *et al.* (2020)'s conceptual framework with only those correlates that may be affected by UA. Below we discuss how UA might affect each correlate and the literature in that area, with a specific focus on the most relevant components: professional development, since this is the core of the program, and student achievement (since the goal of UA is to improve student science performance).

Professional Development. Relatively few quantitative studies have looked at the impacts of *specific* professional development on teacher retention. Coldwell (2017), in a survey of over

500 teachers, and interviews with a subsample, finds evidence professional development impacts teachers' career trajectories and intermediate outcomes. Similarly, Erickson (2007) used nationally representative survey data and found more professional development and higher quality professional development were predictive of less turnover. DiGaudio (2017) examined the use of a specific professional development tool (the School Improvement Engine, or SIE) in NYC schools, and found teacher retention was higher in schools using the tool than other NYC schools, but the analysis was not causal. In contrast, Garet *et al.* (2008), using an experimental design, find no impact of a specific professional development on teacher retention. However, they note teacher turnover itself may have hampered proper delivery of the treatment. Allen and Sims (2017), using data on teachers in England, examined whether STEM professional development courses were associated with improved science teacher retention, and found no impact. Though the evidence is mixed, a recent meta-analysis on correlates of teacher turnover does find teachers who indicate they have good in-service professional development have 16 percent lower odds of leaving than those without (Nguyen *et al.*, 2020).

Student Achievement. The odds of teacher turnover are 10 percent lower for schools with higher student achievement than schools with lower student achievement (Nguyen *et al.*, 2020). If the UA program is successful at improving student achievement, it may impact teacher retention; indeed, a previous study found positive impacts of UA on students' scores on New York State's eighth grade science assessment (Weinstein *et al.*, 2014). Student performance may also improve in ways not captured by standardized exams (e.g. improved attendance or engagement). These student-level impacts may be a mechanism through which the UA program affects teacher turnover.

The UA program may also affect teacher retention by improving *teacher quality;* some research finds higher quality teachers have higher retention (e.g. Vagi *et al.*, 2019). UA may improve teacher quality: program assessments have found UA teachers report more mastery of science content (*About UA*, n.d.). While some studies have questioned the sustainability of content knowledge gained through professional development, teachers who participate in programs that occur during the school year (like UA) lose their knowledge less rapidly (Liu & Phelps, 2020). Getting to engage with content experts on site at ISEIs may be another critical component of meaningful knowledge transfer (Baron *et al.*, 2020). In addition, the current UA framework of inquiry-based, ongoing, and intensive professional development promotes long-term professional growth, which can improve teachers' *career satisfaction*. As reflected in the two-way relationship between personal and school factors in the conceptual framework for correlates of teacher turnover, this improved teacher quality and career satisfaction could affect school characteristics (e.g. lead to improvements in student achievement).

A better *work environment* is critical for lowering teacher turnover and is an important mechanism to explain how UA can promote teacher retention. A recent survey of 1,000 former public school teachers indicates that stress was more important than pay in their decision to leave the profession, even before the COVID-19 pandemic (Diliberti *et al.*, 2021). There is significant evidence that teachers with strong *administrative support* are less likely to turnover (e.g. Kraft *et al.*, 2016; see Nguyen *et al.*, 2020 for a recent meta-analysis). The UA program provides resources for school leadership that may improve the work environment and administrative support, such as principal breakfasts. Because principals and other school staff (e.g. parent coordinators) are involved in UA and contribute to the school's science program, science teachers in UA schools may have a more enriching and supportive environment.

Because UA is a school-level intervention that aims to create a cohort of science teachers across grades, there are increased avenues for *teacher collaboration*, another correlate of teacher turnover (Fuller *et al.*, 2016; Kraft *et al.*, 2016; Nguyen *et al.*, 2020) teamwork. Teachers also engage with a community of their peers outside the school and content experts at participating ISEIs through both professional development sessions and events. For example, UA hosts a citywide year-end event where students come together with friends, families, and educators to present their work at a science exposition, typically held under the blue whale at the American Museum of Natural History, it itself a symbol of the importance of what teachers and students are doing.

UA also provides *teaching materials* (e.g. materials for science labs); while the evidence on the association between school resources broadly and teacher turnover is mixed, literature suggests providing adequate teaching materials does matter to teachers (Nguyen & Spring, 2021, and cites therein).

Finally, there is evidence that many of these factors relevant to teacher retention were particularly important during the COVID-19 pandemic: schools with strong communication, targeted training, meaningful collaboration, and fair expectations were more successful at maintaining teachers' sense of success as the beginning of the pandemic (Kraft *et al.*, 2021).

Summary. Taken together, the UA program provides many of the components of improving personal and school factors that could lead to increased teacher retention. The core of the UA program is professional development, which some literature has found is related to reduced teacher turnover. Literature also suggests other components of the UA program: support for administrators, opportunities for community building within and across schools, supplies, and an improved general work environment, may reduce teacher turnover. Though we cannot separately capture the impact of the various components of the UA program, the literature suggests UA may help keep teachers in NYC schools.

Data, Measures, and Sample

Data

This study draws on three data sets from the NYC DOE, New York State Department of Education, and the UA program. First, we use administrative individual-level longitudinal data on all teaching personnel employed by the NYC DOE, from academic years 2003 to 2022.[1] A unique person and school identifier allow us to track individual teachers across schools in the NYC district and over time. The teacher data include teachers' school, years of teaching experience at the school and in the district, subject taught, and salary. Data on teachers' race/ethnicity, gender, and absences are not available for all years of the sample. While some research finds these are important predictors of teacher retention, earlier research in NYC found no substantial differences in teacher retention based on race/ethnicity or gender (Marinell & Coca, 2013). In addition, our results are fairly robust to the exclusion of all teacher controls that are available (see Tables 3 and 4 Column 1 compared to our main results in Column 5), increasing our confidence that estimates are not significantly biased by these omitted variables.

Second, these teacher-level data are combined with annual administrative records from the UA program to identify teachers who participated from 2005-2021. Third, we use publicly available school-level data from the New York State School Report Cards to measure school-level characteristics, including measures of school quality, teacher quality, and student achievement, that may influence turnover. Specifically, these measures are total school enrollment; percentage of students who are Black, Hispanic, White, and Asian/other race (multiracial or Native American/Alaskan Indian); percentage of students who are English

[1] We refer to academic years by the calendar year of the Spring semester (e.g. the 2002-03 school year is referred to as 2003).

language learners, students with disabilities, and eligible for free or reduced-price lunch; school grade configuration (e.g. K–8, 6–8); percentage of students who met statewide proficiency standards on math and science exams; and pupil-teacher ratio.[2]

Measures

Our variable of interest is participation in the UA program. We operationalize participation two ways. Our primary definition is a dichotomous variable equal to 1 the year a teacher joins the UA program and each year thereafter, and equal to 0 otherwise (*UAPost)* because the skills and professional network teachers develop through UA likely impact their teaching practice even after they are no longer active in the program. Alternatively, we define participation as a dichotomous variable equal to 1 only in the years a teacher is an active participant in UA (*UACurrent*). We expect active participation in UA may have an even stronger association with retention.

The outcome, teacher turnover, is measured two ways: leaving the school and leaving the NYC DOE in the following academic year (that is, outcomes for 2021 capture whether the teacher did not return to their school or district in the 2022 school year). Teachers who leave their school either transfer to another school within the district or leave the district entirely. For districts, teacher mobility between schools within the district has different implications for staffing and cost than teacher mobility out of the district entirely. This main sample considers teachers' first spell, so does not account for teachers who enter and exit schools (or the NYC DOE) more than once. However, redefining the outcome variable to whether a teacher leaves their school (or the NYC DOE) two years later (which means observations for teachers who

[2] We are able to match the school-level data to the teacher-level data for 99% of observations. We replace missing values with the year averages and include indicators in the model for school-level variables that are missing and replaced.

leave for one year, but return to their school or the NYC DOE the following year, are retained), leads to quantitatively similar results (see Appendix Table A1 Column 2).

Sample

Our sample includes all teachers who ever taught science in NYC public middle school grades 6–8, regardless of the grade configuration of the school. We observe when NYC DOE hired each teacher, except for teachers who started before 2003. To capture teachers' full employment history for the survival analysis, our primary analysis sample includes middle school science teachers whom we can observe in their first year of teaching in NYC (cohorts 2003–2021). This eliminates roughly 1,900 teachers in cohorts 1964–2002 (30% of middle school science teachers we observe from 2003-2022), 337 of whom participated in UA (approximately 18% of UA teachers). Our results are robust to this exclusion (see Appendix Table A1 Column 3).

Critical for this analysis is that UA is a school-based program that requires the participation and buy-in of school administrators. Principals who are more proactive might encourage their teachers to sign up for the program, or, alternatively, teachers in less supportive environments might seek opportunities outside of their school. Because UA is in many ways a school-based initiative, and to account for school-level selection, we limit the sample to schools with teachers who participated in UA for at least one year. Excluding schools that might be systematically different from UA schools in ways that influence teacher turnover reduces the sample size and limits the generalizability of findings but strengthens their internal validity. While results are robust when we include schools that never participated in UA (see Table 4 Column 4), the magnitude of the associations are different. Teachers in non-UA schools may not be an appropriate counterfactual for teachers in UA schools, given schools must opt-into the UA program, which is why our preferred analysis is limited to teachers in UA schools. In addition, to address concerns that contemporary school-level controls are endogenous (i.e. school characteristics may change in response to a school's participation in UA), in a robustness analysis we use school-level controls from the 2004 academic year, before any school joined the UA program; the results are quantitatively similar (see Appendix Table A1 Column 5).

Table 1 Column 1 presents descriptive statistics for the full sample of science teachers who ever taught in an ever-UA school, and Columns 2 and 3 break out teachers who ever or never participated in UA. The sample includes 1,009 UA science teachers (approximately one-third of the sample). The longest time we can track a teacher in the sample is 19 years (from school years 2003–2021).[3] Most teachers have five years or less of teaching experience (57% of the observations in the full sample). On average, UA participants have more teaching experience than non-UA participants (5.5 versus 4.8 years), and higher average salaries. UA teachers are in the program for five years, and 4.6% of their colleagues (all other teachers in the school) are also UA teachers, on average. Lastly, UA teachers are less likely to leave their school (13% vs. 21%) or the district (3% vs. 10%) the following year.

Methods

We estimate discrete-time hazard models that identify the change in the hazard probability of exit by comparing teacher turnover before and after middle school science teachers join the UA program, and account for unobserved heterogeneity using teacher random effects. Because logit coefficients are not directly interpretable, all results are expressed as average marginal effects unless otherwise noted.

[3] Recall results for 2021 capture whether a teacher left the school or district in 2022. Outcomes for the 2021 observations are based on 2022 data; we do not have 2023 data so cannot include 2022 observations in the model.

We estimate the following discrete-time hazard logit model:

$$logit\ (h_{its}) = \boldsymbol{D'}_{\boldsymbol{it}}\boldsymbol{\alpha} + \delta UA_{its} + \boldsymbol{X'}_{\boldsymbol{its}}\boldsymbol{\beta} + u_i \quad (1)$$

where the hazard function $h_{its} = \Pr\ (exit_{its} = 1)$ is equal to the probability that teacher *i* leaves their school *s* in year *t+1* conditional on still being employed in year *t*. We also examine exit out of the district as a secondary outcome. $\boldsymbol{D}$ is a vector of period indicators (one for each time period 1 through 19) that represent the baseline hazard. The marginal effect of these period indicators will give us the hazard probability of exit in each time period. Adding an indicator variable for each period is the most flexible representation and does not impose any particular shape on the baseline hazard. The baseline hazard only predicts the time effect, without differentiating teachers by their respective characteristics (i.e., duration dependence). *UA* is the indicator *UAPost* or *UACurrent*, and the marginal effect of *UA* is the association between UA participation and the hazard function.

The vector $\boldsymbol{X}$ includes the school-level characteristics described in the data section above, which could impact program participation and teacher turnover, available teacher characteristics (whether they are currently teaching science and their salary), as well as year effects to account for time-varying factors that may affect teacher labor market decisions common to all teachers (e.g., economic recession), cohort effects to adjust for differences in the 19 entering cohorts of teachers from 2003–2021, and local (community) school district effects. Community districts, based on geography, can affect school choice and residential decisions, and thus the characteristics of students and schools.

If unobserved heterogeneity exists and we ignore it, our hazard estimate will be biased. To illustrate this point, imagine there are two types of science teachers: one group that has a strong preference to teach and has a low risk of leaving their job and another group that took the job out of necessity and has a high risk of exit. Further, assume that each group's risk of leaving teaching is different across the two groups, but is constant over time. The low-risk group may have a 1 in 10 chance of leaving each year, whereas the high-risk group may have a 1 in 3 chance of leaving. In time period 1, the high-risk group is more likely to exit; consequently, the remaining group of teachers now has fewer high-risk teachers. If we ignore these differences in teachers (such as their love of teaching) we may see declining hazards over time merely as a consequence of aggregation across different groups although the groups themselves have *constant* (but different) hazards over time. To ensure there are no unobservable individual confounders associated with a teacher's probability of exit and participation in UA, we accommodate for unobserved heterogeneity among teachers by adding a teacher-specific error term, u_i (random effect). We also estimate a model that accounts for school-level unobserved heterogeneity by replacing u_i with a school-specific error term. All standard errors are clustered at the school level.

Results

Figure 2 and Table 2 provide descriptive evidence that turnover is higher for science teachers in NYC than for teachers in other subjects. The survival probabilities show the unadjusted fraction of teachers who remain teaching at their school in each period, for cohorts 2003–2021. When teachers enter the district (in time period 0) the survival is 1 (or 100%). In the following year (time period 1), the share drops to a 0.80 for teachers of subjects other than math or science and approximately 0.73 for math and science teachers. Note that the largest decline in survival rates for all subjects is in the first year of teaching, and over time attrition in each period diminishes. We present only three groups in Figure 2 and Table 2 for readability, but we also separately examined English, social studies, and special education, which all have higher retention than science. Overall, in 2004 (the year before UA began) 17% of all teachers, and 20% of middle school science teachers, left their school the following year. This is similar to turnover rates over the entire 2003-2021 period, when on average, 18% of teachers left their school the following year and 20% of middle school science teachers left their school the following year.

Our primary finding is that compared to non-UA science teachers, UA science teachers are less likely to leave their school and less likely to leave the NYC DOE. This finding is consistent across different model specifications and samples. Table 3 presents hazard model estimates of the association of UA on the probability that a science teacher leaves the school and Table 4 presents hazard model estimates of the association of UA with the probability that a science teacher leaves the district, conditional on not having left until that point. Column 1 only accounts for year effects, cohort, and community school district effects. Columns 2 and 3 successively add observable teacher and school characteristics. Column 4 additionally accounts for school-level unobserved heterogeneity (school random effect). Column 5 accounts for individual unobserved heterogeneity (teacher random effect, as reflected in equation 1). Column 6 also includes the teacher random effect reflected in equation 1, but replaces our preferred indicator of UA participation (participating in the current or any prior year, *UAPost*) with an indicator for active UA participation in the given year (*UACurrent*). We show all of these specifications for completeness but focus our discussion of the results on our preferred specification that accounts for individual heterogeneity (Columns 5 and 6).

There are two important takeaways from Table 3. First, in the preferred specification in Column 5, UA science teachers are 3.8 percentage points (pp) less likely to leave their school in the following academic year. This change represents a 20% decline in baseline turnover rates. To put this in perspective, studies that have investigated the impact of monetary incentives in hard-to-staff schools and subjects have estimated up to a 30% reduction in turnover (Clotfelter *et al.*, 2008; Cowan & Goldhaber, 2018). The association is even greater for UA teachers currently participating in UA (Column 6)—they are 4.8 percentage points less likely to leave their school in the following academic year.

Second, after adjusting for observable teacher and school characteristics among UA-participating schools, unobserved heterogeneity among teachers is relatively unimportant in predicting whether a teacher will leave their *school*. The estimation statistics at the bottom of Columns 5 and 6 reiterate this point. Rho (ρ) denotes the share of the total variance in the probability of exit that can be attributed to variance in unobserved teacher heterogeneity. For models with leaving the school as the outcome, rho is not statistically different from zero in both Columns 5 and 6 (as indicated by p values above 0.10).[4] In other words, the baseline hazard and observable predictors model the hazard probability of exit relatively well.

Third, the baseline hazard shows that the probability of attrition for science teachers declines over time (negative duration dependence). This is further illustrated in Figure 3, which is a graphical representation of estimates in Column 5 of Table 3, calculated for each time period 1-18.[5] In all time periods, UA teachers (dashed line) are less likely than non-UA teachers (solid line) to leave their school. The gap is wider at the start of a teacher's career, consistent with existing literature that suggests that teacher attrition is the highest for novice teachers. Importantly, benefits of the UA program remain through Year 18.

Table 4 presents analogous results for the probability of leaving the NYC public school district. UA science teachers are 3.6 percentage points less likely to leave the NYC school

[4] While rho is statistically different from zero in the model with school-level random effects (Column 4), we note that the estimated relationship between UA and attrition is almost identical in this model.
[5] While we can follow teachers for up to 19 years, none of the teachers we observe in their 19th year of teaching leave their school or the district. Therefore, we cannot estimate hazards for $t = 19$.

district than non-UA science teachers (Column 5). Again, the associations are greater for active UA teachers, who are 3.9 percentage points less likely to leave the district (Column 6). However, unlike the results for leaving the school, some of the variance in the probability of exiting the district can be attributed to variance in unobserved school or teacher heterogeneity (as reflected in the estimation statistics at the bottom of Columns 4, 5, and 6 in Table 4). That is, there are unobserved school or teacher characteristics that predict their likelihood of leaving the district. If these characteristics are correlated with participation in UA, our estimates of the association of UA participation and the probability of leaving the district may be biased. As previously stated, we do not interpret our estimates as causal, and particularly for estimated associations with exiting the district, we are more cautious in interpreting these estimates. However, as with results for leaving the school, results for leaving the district suggest benefits of UA to teachers with varying levels of experience. In Figure 4, we see that in all time periods, UA teachers (dashed line) are less likely than non-UA teachers (solid line) to leave the district. The gap is wider at the start of a teacher's career, narrows between Years 5 and 11, and then widens again between Years 12 and 18.

Taken together, the results suggest that the UA program, initially designed to improve students' science achievement, is also associated with improved retention among science teachers in NYC middle schools; the magnitude of these associations are practically significant.

Sensitivity analyses

We conduct four additional analyses to examine whether our main findings are sensitive to our analytic decisions and present the results in Table 4a (estimating the probability a science teacher leaves the school) and Table 4b (estimating the probability a science teacher leaves the district). Column 1 in both tables replicates the main results (from Column 5 of Tables 2 and 3) for comparison. First, Column 2 of Table 4 presents results where the outcomes are defined as leaving the school or district two years later, to account for teachers who leave temporarily for one year and come back. Second, Column 3 of Table 4 presents results when we relax the restriction that we must observe a teacher's full employment history and add back prior cohorts of science teachers (i.e. cohorts prior to 2003). Third, Column 4 of Table 4 presents results when we add back science teachers in schools that never participated in UA. Fourth and finally, Column 5 of Table 4 presents results when we control for school characteristics as of 2004, before any school participated in UA, rather than using time-varying school characteristics as controls. All of the results are similar. The estimates for the association between UA participation and reduced likelihood of leaving the school range from 3.5-4.2 percentage points; estimates for the association between UA participation and reduced likelihood of leaving the NYC DOE range from 3.5-4.5 percentage points. The differences in magnitude may be due to selection issues previously discussed. For example, estimates for teachers' likelihood of leaving the school in the sample that uses all schools (i.e. is not limited to schools that ever participate in UA) are slightly higher than our main estimates. This is expected, given schools that select to participate in UA may have better teacher retention than schools without UA, even absent the program.

Conclusion

The UA program is a unique formal–informal partnership made possible through an ongoing collaboration between participating ISEIs and the NYC DOE. Despite the growing number of informal collaborations between schools and external institutions, research on the impact of such partnerships is sparse, particularly on teacher retention. This study examines changes in the risk of teacher turnover after UA participation. To do so, we take advantage of rich longitudinal data on science teachers in NYC middle schools. We identify the timing of teachers' UA program participation and estimate logit hazard models that account for unobserved heterogeneity among teachers. Taken together, the results suggest that UA significantly reduces the risk of leaving a school by four percentage points and reducing the risk of leaving the district by three percentage points.

Although this study does not empirically examine the specific mechanisms by which UA is influencing teacher turnover, several components of the UA program may improve retention, such as professional development and mentorship, enhanced collaboration among teachers and administrators in schools, and more engaged/higher-performing students.

Teacher turnover has both financial and academic consequences for schools and districts. Though our results are not causal, and we do not conduct a formal benefit-cost analysis, it is possible that high-quality professional development, such as that provided by the UA program, is a cost-effective intervention for teacher retention. This may be especially true if improved teacher retention is one of multiple benefits of the UA program—that is, the primary objective is to improve student science outcomes, and improved teacher retention is a spillover benefit.[6]

Though the UA program is specific to NYC, school districts in urban areas have a unique opportunity to take advantage of the concentration of science-rich cultural institutions in their cities. More than 70% of science-rich cultural institutions in the United States have programs that are specifically designed for schools and teachers, but few of them have been formally

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[6] Though we do not consider the effect of the UA program on student outcomes, it is possible that it affects student outcomes directly *and* that improved teacher retention is a mechanism for improvements in student outcomes. That is, the UA program may improve a student's outcomes because the quality of their science teaching improves, in cases where a science teacher would have remained even in the absence of the UA program. It is also possible the UA program improves students' outcomes because they have a science teacher who would have otherwise left their school or the NYC DOE. See Goldhaber & Cowan (2014) for a similar discussion in their analysis of teacher preparation programs considering both direct effects on student achievement and effects considering teacher turnover.

institutionalized (Bevan *et al.*, 2010; Philips *et al.*, 2007). All states and districts allocate time and financial resources specifically to professional development (Loeb *et al.*, 2009). While UA is an innovative intervention, it is possible for other school districts to implement similar programs.

Results from this paper give insight into measures policymakers and school administrators can take to improve working conditions and workplace satisfaction and promote teacher retention, such as content-focused professional development and classroom instruction support, especially in schools and subjects that struggle most with teacher turnover. Our results also highlight that school-community educational partnerships, which are typically able to mobilize many different resources, can have an important role in supporting not only students but also teachers.

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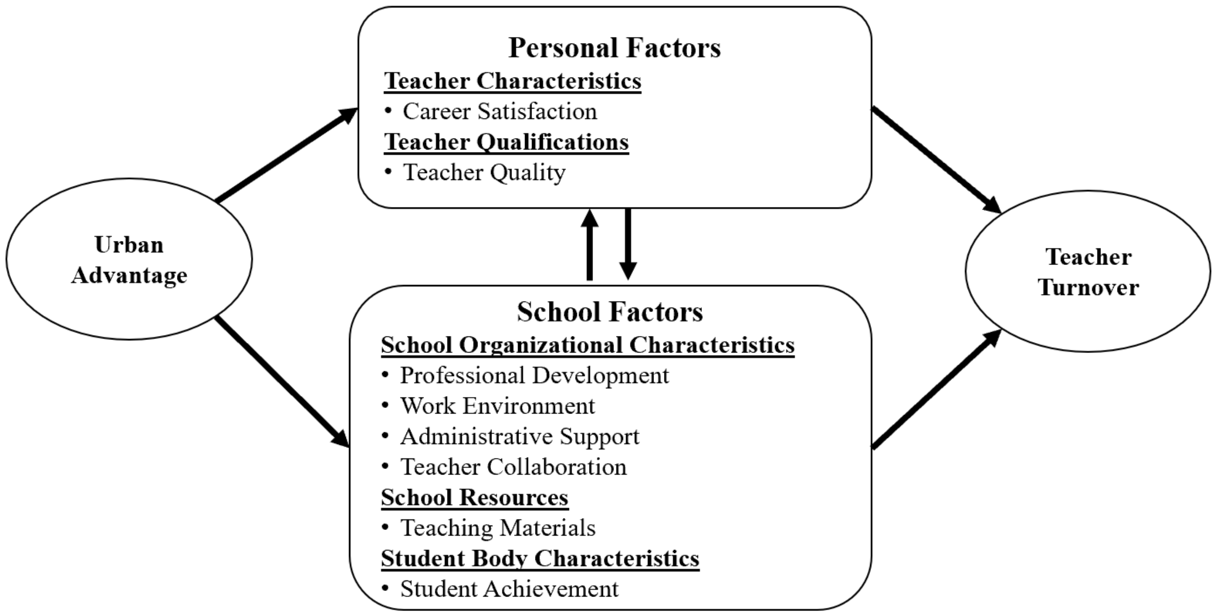
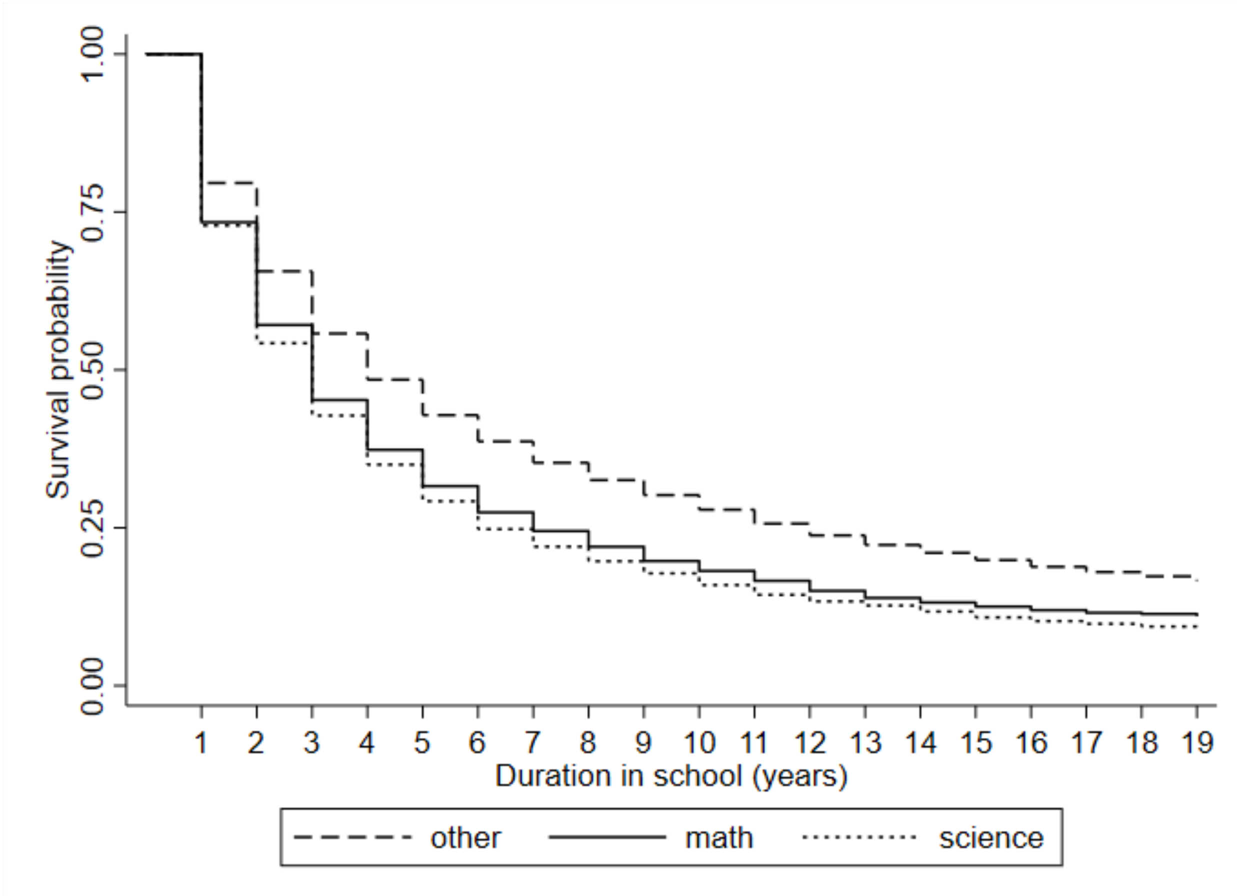
Figure 1. Conceptual Framework: Correlates of teacher turnover that might be affected by the Urban Advantage program.



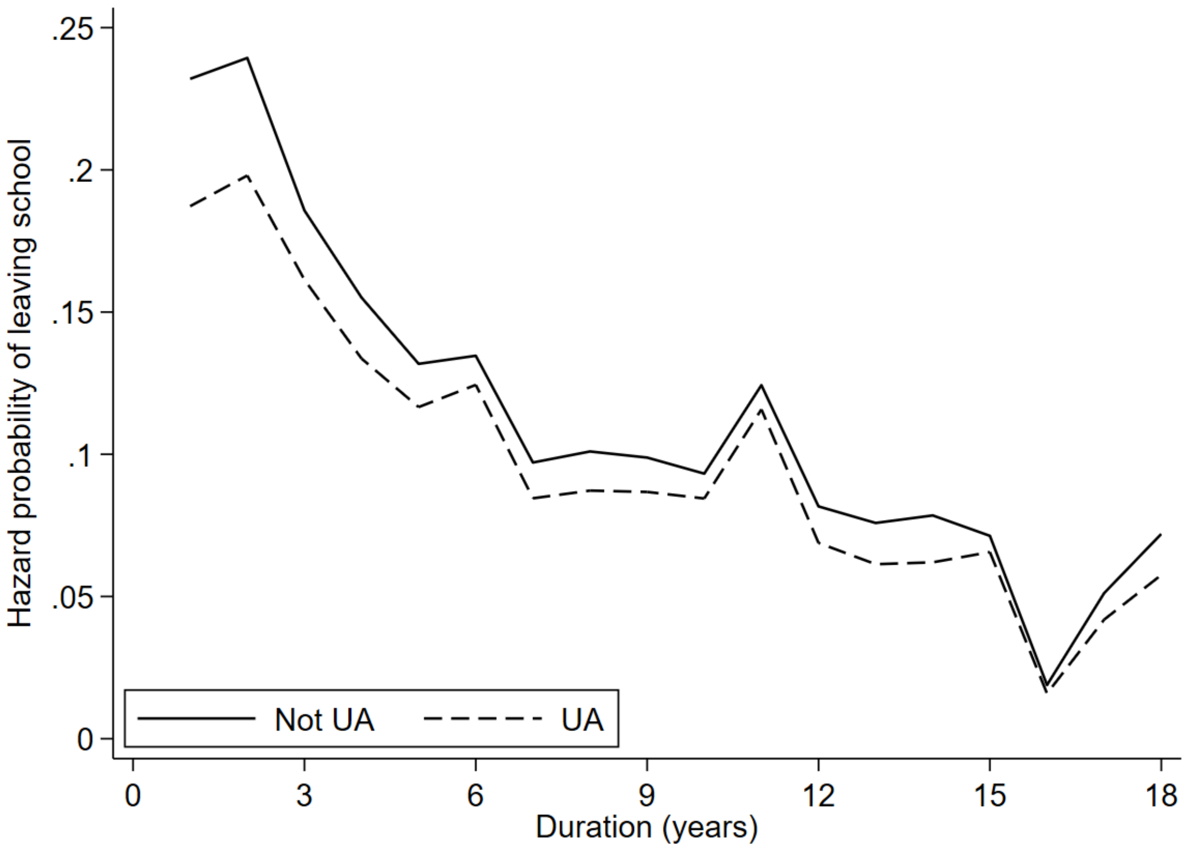
Note. This is a modified version of the conceptual framework in Nguyen *et al.* (2020), presenting only those correlates through which Urban Advantage might be affect teacher turnover.

Figure 2. Kaplan-Meier survival estimates of teaching in the same school the following academic year.



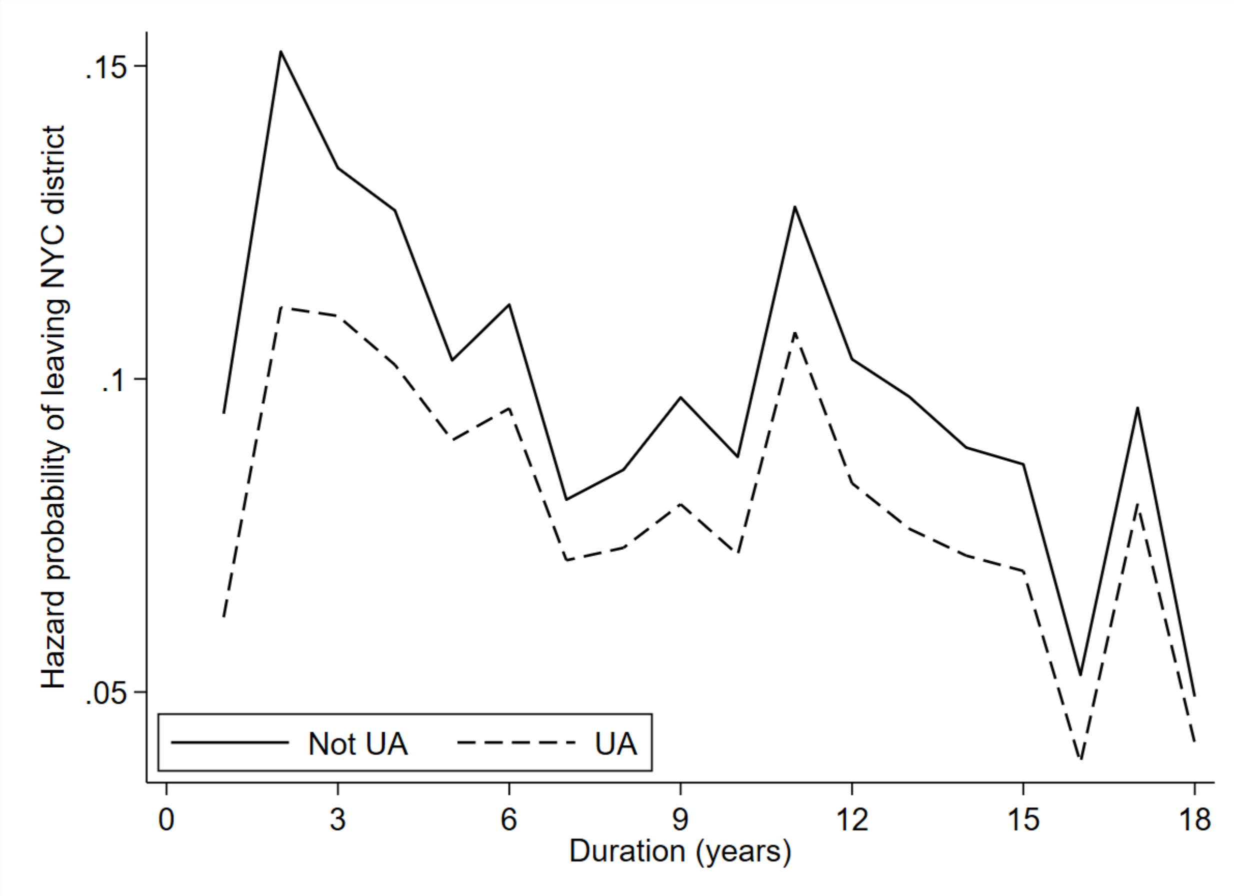
Notes: This figure illustrates the proportion of teachers who remain teaching in the same school the following academic year. The sample includes all teachers observed in their first year of teaching in New York City public schools (entering cohorts 2003–2021); results are similar (retention is the lowest among science teachers) when the sample is limited to teachers who ever work in middle schools (schools serving Grades 6-8).

Figure 3. Estimated hazard for the probability that a science teacher leaves the school in the following year.



Note: The sample includes New York City public middle schools that ever participated in the Urban Advantage (UA) program and teachers who ever taught science in Grades 6–8 and were observed in their first year of teaching (entering cohorts 2003–2021). Results are average predicted probabilities from estimating Model 1 in the paper for each time period $t = 1$ through $t = 18$. UA = Urban Advantage.

Figure 4. Estimated hazard for the probability that a science teacher leaves the district in the following year.



Note: The sample includes New York City public middle schools that ever participated in the Urban Advantage (UA) program and teachers who ever taught science in Grades 6–8 and were observed in their first year of teaching (entering cohorts 2003–2021). Results are average predicted probabilities from estimating Model 1 in the paper for each time period $t = 1$ through $t = 18$. UA = Urban Advantage.

Table 1. Average characteristics of science teachers in ever-UA schools, cohorts 2003–2021

	All teachers (1)	Ever UA (2)	Never UA (3)
Number of teachers	3,311	1,009	2,302
Total number of teacher-year observations	23,126	8,801	14,325
(% of sample)		(38%)	(62%)
Annual salary ($)	67,156	68,663	66,229
Teaching experience (%):			
1 year or less	15%	12%	17%
2–3 years	24%	22%	25%
4–5 years	18%	18%	18%
6–10 years	28%	31%	27%
10+ years	15%	18%	14%
Average years teaching at NYC DOE	5.0	5.5	4.8
Average years in UA	1.9	5.0	0.0
Colleagues in School in UA (%)	3.0%	4.6%	2.0%
Turnover in following year (%):			
Left school	18%	13%	21%
Left district	7%	3%	10%
Changed schools within district	10%	9%	11%
Turnover in 5 years (%):			
Left school	68%	64%	70%
Left district	48%	43%	51%
Changed schools within district	20%	21%	19%

Table 2. Kaplan-Meier survival estimates of teaching in the same school the following academic year

Period	Science Teachers	Math Teachers	All Other Teachers
1	0.7287	0.7337	0.7960
2	0.5423	0.5711	0.6562
3	0.4277	0.4523	0.5576
4	0.3500	0.3735	0.4845
5	0.2921	0.3160	0.4284
6	0.2478	0.2743	0.3867
7	0.2201	0.2448	0.3530
8	0.1971	0.2200	0.3255
9	0.1778	0.1974	0.3018
10	0.1593	0.1817	0.2787
11	0.1438	0.1661	0.2565
12	0.1335	0.1501	0.2380
13	0.1269	0.1389	0.2229
14	0.1174	0.1317	0.2103
15	0.1081	0.1252	0.1988
16	0.1023	0.1196	0.1883
17	0.0980	0.1155	0.1800
18	0.0937	0.1137	0.1732
19	0.0884	0.1111	0.1662

Notes: This table reflects the proportion of teachers who remain teaching in the same school the following academic year (graphed in Figure 1). The sample includes all teachers observed in their first year of teaching in New York City public schools (entering cohorts 2003–2021); results are similar (retention is the lowest among science teachers) when the sample is limited to teachers who ever work in middle schools (schools serving Grades 6-8).

Table 3. Probability that a science teacher leaves the school the following year

	(1)	(2)	(3)	(4)	(5)	(6)
UAPost	-0.031***	-0.036***	-0.038***	-0.040***	-0.038***	.
	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)	.
UACurrent	.	.	.	.	.	-0.048***
	.	.	.	.	.	(0.009)
Baseline hazard						
D_{02}	0.002	0.004	0.006	0.007	0.006	0.007
	(0.017)	(0.018)	(0.017)	(0.015)	(0.015)	(0.015)
D_{03}	-0.064**	-0.060**	-0.057**	-0.055**	-0.057**	-0.055**
	(0.027)	(0.027)	(0.027)	(0.022)	(0.023)	(0.024)
D_{04}	-0.110***	-0.105***	-0.101***	-0.099***	-0.101***	-0.099***
	(0.033)	(0.035)	(0.034)	(0.028)	(0.029)	(0.032)
D_{05}	-0.149***	-0.143***	-0.137***	-0.134***	-0.137***	-0.135***
	(0.040)	(0.041)	(0.041)	(0.033)	(0.033)	(0.033)
D_{06}	-0.153***	-0.146***	-0.139***	-0.137***	-0.139***	-0.138***
	(0.044)	(0.046)	(0.045)	(0.037)	(0.037)	(0.037)
D_{07}	-0.204***	-0.196***	-0.189***	-0.188***	-0.189***	-0.188***
	(0.048)	(0.050)	(0.049)	(0.039)	(0.039)	(0.048)
D_{08}	-0.213***	-0.204***	-0.198***	-0.197***	-0.198***	-0.196***
	(0.050)	(0.053)	(0.052)	(0.041)	(0.044)	(0.055)
D_{09}	-0.224***	-0.215***	-0.210***	-0.210***	-0.210***	-0.209***
	(0.052)	(0.054)	(0.053)	(0.042)	(0.048)	(0.065)
D_{10}	-0.235***	-0.227***	-0.221***	-0.221***	-0.221***	-0.219***
	(0.054)	(0.057)	(0.056)	(0.043)	(0.052)	(0.048)
D_{11}	-0.224***	-0.215***	-0.210***	-0.209***	-0.210***	-0.208***
	(0.058)	(0.061)	(0.060)	(0.048)	(0.052)	(0.068)
D_{12}	-0.253***	-0.247***	-0.241***	-0.242***	-0.241***	-0.240***
	(0.053)	(0.055)	(0.054)	(0.043)	(0.060)	(0.043)
D_{13}	-0.257***	-0.252***	-0.247***	-0.247***	-0.247***	-0.246***
	(0.055)	(0.057)	(0.055)	(0.043)	(0.064)	(0.043)
D_{14}	-0.258***	-0.252***	-0.247***	-0.248***	-0.247***	-0.246***
	(0.056)	(0.058)	(0.057)	(0.044)	(0.065)	(0.044)
D_{15}	-0.261***	-0.255***	-0.250***	-0.251***	-0.250***	-0.249***
	(0.055)	(0.058)	(0.056)	(0.044)	(0.067)	(0.044)
D_{16}	-0.282***	-0.275***	-0.271***	-0.272***	-0.271***	-0.269***
	(0.047)	(0.049)	(0.048)	(0.037)	(0.078)	(0.037)
D_{17}	-0.271***	-0.265***	-0.260***	-0.261***	-0.260***	-0.258***
	(0.052)	(0.054)	(0.053)	(0.043)	(0.072)	(0.042)
D_{18}	-0.258***	-0.252***	-0.248***	-0.249***	-0.248***	-0.247***
	(0.064)	(0.066)	(0.064)	(0.050)	(0.069)	(0.050)
N	12,936	12,936	12,936	12,936	12,936	12,936
ρ	n/a	n/a	n/a	0.0162	0.0001	0.0015
p-value	n/a	n/a	n/a	0.001	0.486	0.481
Teacher characteristics		x	x	x	x	x
School characteristics			x	x	x	x

Table 3. Probability that a science teacher leaves the school the following year

	(1)	(2)	(3)	(4)	(5)	(6)
School random effects				x		
Teacher random effects					x	x

Standard errors clustered by school in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Notes: All estimates are average marginal effects. The sample includes New York City public middle schools that ever participated in the Urban Advantage (UA) program and teachers who ever taught science in Grades 6–8 and were observed in their first year of teaching (entering cohorts 2003–2021). All models include year, cohort, and district effects. Teacher characteristics include salary and an indicator if they are a science teacher in the current year. ρ denotes the total variance in the outcome contributed by school level variance (Column 4) and teacher level variance (Columns 5 and 6). The p-value is for the null hypothesis that ρ is equal to zero. The highlighted estimate is the main result.

Table 4. Hazard model estimates: Probability that a science teacher leaves the school district the following year

	(1)	(2)	(3)	(4)	(5)	(6)
UAPost	-0.016***	-0.021***	-0.025***	-0.025***	-0.036***	.
	(0.004)	(0.004)	(0.004)	(0.004)	(0.006)	.
UACurrent	.	.	.	.	.	-0.039***
	.	.	.	.	.	(0.006)
Baseline hazard						
D_{02}	0.013	0.014	0.016	0.016	0.016	0.028**
	(0.014)	(0.014)	(0.014)	(0.013)	(0.012)	(0.013)
D_{03}	-0.079***	-0.076***	-0.072***	-0.071***	-0.060***	-0.044***
	(0.016)	(0.016)	(0.016)	(0.014)	(0.015)	(0.015)
D_{04}	-0.142***	-0.139***	-0.134***	-0.133***	-0.122***	-0.100***
	(0.017)	(0.017)	(0.017)	(0.015)	(0.017)	(0.017)
D_{05}	-0.214***	-0.208***	-0.202***	-0.200***	-0.192***	-0.164***
	(0.018)	(0.019)	(0.019)	(0.016)	(0.017)	(0.019)
D_{06}	-0.242***	-0.233***	-0.228***	-0.226***	-0.225***	-0.192***
	(0.019)	(0.020)	(0.020)	(0.017)	(0.018)	(0.020)
D_{07}	-0.299***	-0.287***	-0.282***	-0.281***	-0.290***	-0.252***
	(0.021)	(0.023)	(0.023)	(0.018)	(0.018)	(0.021)
D_{08}	-0.315***	-0.302***	-0.297***	-0.296***	-0.313***	-0.269***
	(0.023)	(0.025)	(0.025)	(0.019)	(0.018)	(0.022)
D_{09}	-0.328***	-0.315***	-0.310***	-0.309***	-0.334***	-0.284***
	(0.024)	(0.026)	(0.026)	(0.019)	(0.019)	(0.023)
D_{10}	-0.346***	-0.333***	-0.327***	-0.327***	-0.362***	-0.307***
	(0.026)	(0.028)	(0.028)	(0.020)	(0.019)	(0.024)
D_{11}	-0.346***	-0.333***	-0.328***	-0.328***	-0.367***	-0.310***
	(0.026)	(0.028)	(0.028)	(0.020)	(0.020)	(0.025)
D_{12}	-0.361***	-0.349***	-0.343***	-0.343***	-0.392***	-0.330***
	(0.027)	(0.029)	(0.029)	(0.021)	(0.021)	(0.026)
D_{13}	-0.367***	-0.355***	-0.350***	-0.350***	-0.405***	-0.340***
	(0.027)	(0.030)	(0.030)	(0.021)	(0.021)	(0.027)
D_{14}	-0.371***	-0.359***	-0.354***	-0.354***	-0.414***	-0.347***
	(0.027)	(0.030)	(0.030)	(0.021)	(0.022)	(0.027)
D_{15}	-0.374***	-0.362***	-0.357***	-0.357***	-0.420***	-0.351***
	(0.027)	(0.030)	(0.030)	(0.021)	(0.022)	(0.027)
D_{16}	-0.377***	-0.365***	-0.359***	-0.360***	-0.426***	-0.356***
	(0.027)	(0.030)	(0.030)	(0.021)	(0.023)	(0.027)
D_{17}	-0.376***	-0.364***	-0.359***	-0.359***	-0.425***	-0.355***
	(0.027)	(0.030)	(0.030)	(0.021)	(0.023)	(0.028)
D_{18}	-0.378***	-0.366***	-0.360***	-0.361***	-0.429***	-0.358***
	(0.027)	(0.030)	(0.030)	(0.021)	(0.023)	(0.028)
N	23,037	23,037	23,037	23,037	23,037	23,037
ρ	n/a	n/a	n/a	0.0215	0.3108	0.2122
p-value	n/a	n/a	n/a	<0.001	<0.001	<0.001
Teacher characteristics		x	x	x	x	x

Table 4. Hazard model estimates: Probability that a science teacher leaves the school district the following year

	(1)	(2)	(3)	(4)	(5)	(6)
School characteristics			x	x	x	x
School random effects				x		
Teacher random effects					x	x

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

Notes: All estimates are average marginal effects. The sample includes New York City public middle schools that ever participated in the Urban Advantage (UA) program and teachers who ever taught science in Grades 6–8 and were observed in their first year of teaching (entering cohorts 2003–2021). All models include year, cohort, and district effects. Teacher characteristics include salary, and an indicator if they are a science teacher in the current year. ρ denotes the total variance in the outcome contributed by school level variance (Column 4) and teacher level variance (Columns 5 and 6). The p-value is for the null hypothesis that ρ is equal to zero. The highlighted estimate is the main result.

Table 5. Hazard Model Estimates – Sensitivity Analyses

5a. Probability that a science teacher leaves the school					
	Main Results	T+2	All Cohorts	All Schools	2004 School Char.
	(1)	(2)	(3)	(4)	(5)
UAPost	-0.038***	-0.037***	-0.036***	-0.042***	-0.035***
	(0.009)	(0.011)	(0.006)	(0.008)	(0.008)
N	12,936	10,786	21,483	19,356	12,936
ρ	0.0001	0.0610	0.0034	<0.0001	<0.0001
p-value	0.486	0.157	0.460	0.482	0.487
5b. Probability that a science teacher leaves the district					
	Main Results	T+2	All Cohorts	All Schools	2004 School Char.
	(1)	(2)	(3)	(4)	(5)
UAPost	-0.036***	-0.039***	-0.045***	-0.035***	-0.035***
	(0.006)	(0.008)	(0.007)	(0.005)	(0.006)
N	23,037	19,947	38,077	30,057	23,037
ρ	0.3108	0.3868	0.5018	0.2576	0.3034
p-value	<0.001	<0.001	<0.001	<0.001	<0.001

Standard errors clustered by school in parentheses. *** $p < 0.01$.

Notes: All estimates are average marginal effects. The sample includes New York City public middle schools that ever participated in the Urban Advantage (UA) program and teachers who ever taught science in Grades 6–8. All models include year, cohort, and district effects; teacher characteristics; school characteristics; and teacher random effects. Teacher characteristics include salary, and an indicator if they are a science teacher in the current year; in the model with all cohorts, we also include controls for teacher experience at the school and the district, given we do not observe the full employment history for teachers hired prior to 2003. ρ denotes the total variance in the outcome contributed by teacher level variance. The *p*-value is for the null hypothesis that ρ is equal to zero. Column 1 reproduces the main results from Table 2 Column 5. Column 2 redefines the outcome to be leaving the school/district two years later. Column 3 includes all cohorts (i.e. includes cohorts prior to 2003). Column 4 includes all schools (i.e. includes schools that never have a UA teacher). Column 5 uses school-level controls from 2004 (rather than time-varying school level controls used in the main specification).