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Excavating the Teacher Pipeline

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We analyze the placement and attrition patterns of teachers by training programs and document large differences in the rate at which teachers exit both their schools and the profession. These differences are robust to within-school comparisons and little of the difference is explainable by teacher credentials or demographic characteristics. Moreover, we estimate that differences in attrition rates are important in explaining the likely changes in student achievement that would result from varying the proportion of graduates from the most and least effective programs within a state.

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I. Introduction

There is a new focus at both the federal and state levels on teacher training, and whether teacher preparation programs can be improved through changes to pre-service training or accountability measures. Recently, policymakers have begun to consider measures tying financing for tuition to the performance of program graduates (Adelman, Carey, Dillon, Miller, & Silva, 2011; Henry, Kershaw, Zulli, & Smith, 2012; United States Department of Education, 2011). A proposal from the United States Department of Education would redirect aid from the existing TEACH grant program toward students at programs that have historically graduated more effective teachers (United States Department of Education, 2011). These policies are premised on the conclusion that there are meaningful differences in the quality of teachers across programs. A number of recent papers have reached divergent conclusions about the importance of teacher preparation programs as a predictor of teacher effectiveness, measured by the test achievement of their students.[1] The length of time teachers from various pathways spend in the profession has received far less attention. There are a few studies on differences in retention rates based on certification route of entry into the profession (Boyd, Grossman, Lankford, Loeb, & Wyckoff, 2006; Kane, Rockoff, & Staiger, 2008), but none that focuses on variation in attrition among traditional teacher preparation programs. This is a significant knowledge gap given the importance of teaching experience and the costs of teacher recruitment, selection, and initial training.

In this paper we report findings from research analyzing variation in the mobility of teachers across preparation programs. Using data from Washington State, we study the teacher labor market decisions for teachers across 20 programs over a 22 year period. To our knowledge

[1] For instance, see Boyd et al., 2009; Gansle et al., 2012; Goldhaber et al., 2013; Koedel et al., 2012; Mihaly et al., 2012. Findings from these papers are discussed more extensively below.

this is the first study to examine differences in the tenure of teachers by preparation program. Although more modest than the differences across licensure pathways, we find substantial differences in the probability of exiting teaching across traditional preparation programs. In our sample, 7 percent of teachers exit the workforce each year. Controlling for school and assignment characteristics, we find that graduates of the programs with the highest attrition are about 0.5 percentage points less likely to leave the workforce than out-of-state teachers while graduates of the programs with the lowest attrition are about 4-5 percentage points less likely to exit. While about 16 percent of teachers exit their school each year, the range of program effects we estimate is nearly 7 percentage points. For context, the range of mobility effects we observe is approximately equal to the effect on mobility of a $1,800 bonus paid to teachers in low-income schools in North Carolina (Clotfelter, Glenni, Ladd, & Vigdor, 2008).

Importantly, when we combine our estimates of the probability of leaving the profession with estimates of program value-added and allow the differences across programs to decay over time, we show that value-added measures alone may provide incomplete information about the overall effects of program graduates on student achievement. There are two reasons for this divergence. First, the variation in value-added across programs may be greater for recent graduates than for more experienced teachers (Goldhaber et al., 2013). Second, attrition from the profession and teacher turnover may influence how differences in average value-added across programs are translated into differences in student achievement. This is an important finding given the current policy push to regulate teacher preparation programs according to the value-added of the teachers they graduate. Our results suggest that if policymakers decide to tie licensure or student aid eligibility to attendance at particular preparation programs, they should be cognizant both of differences in teacher quality and differences in career pathways.

II. Background

Over the past decade states have increasingly experimented with allowing individuals to enter teaching through alternative pathways, such as the Teaching Fellows program or Teach for America, that do not require completion of a traditional education degree program as a prerequisite for starting teaching.[2] Consequently, teachers who enter the profession from these routes typically have much less formal preparation for teaching. While research on the effectiveness of teachers with different pre-service experiences has come to differing conclusions about mean differences in effectiveness, it appears that the variation within certification routes is much greater than the variation across routes (Boyd et al., 2006; Kane et al., 2008).

More recently, several papers have looked within teacher preparation pathways and considered the outcomes of students taught by teachers from different traditional preparation programs. The variation in the effectiveness of graduates from different preparation programs appears to differ to some degree with the state context and empirical method (Boyd, Grossman, Lankford, Loeb, & Wyckoff, 2009; Gansle, Noell, & Burns, 2012; Goldhaber, Liddle, & Theobald, 2013; Koedel, Parsons, Podgursky, & Ehlert, 2012; Mihaly, McCaffrey, Sass, & Lockwood, 2012; Plecki, Elfers, & Nakamura, 2012). However, teacher preparation programs do not appear to explain a great deal of the variation in measured teacher effectiveness.

In this study, we focus on differences in the attrition rates of teachers across preparation programs. Teacher attrition has both financial and academic consequences for districts and students. There is little available information on the financial costs to school districts of teacher turnover, primarily because of the difficulty in tallying the various administrative, training, and recruitment costs associated with hiring a new teacher. However, the costs associated with

[2] Although they may enter teaching without having completed a traditional teacher preparation program, many alternative certification teachers and Teach for America fellows enroll in a Master's program while they are teaching in order to satisfy state certification requirements (Boyd et al., 2006; Decker, Mayer, & Glazerman, 2004).

turnover may be substantial. Barnes, Crowe, & Schaefer (2007) estimate the cost of teacher exits at $9,500 per teacher for Chicago Public Schools and $8,371 for Milwaukee Public Schools. Their estimates include the direct costs of recruitment and hiring as well as indirect costs such as training, orientation, and professional development. Local and federal governments also have a financial interest in the level of teacher turnover. Currently, students enrolled in recognized preparation programs may be eligible for a combination of state and federal conditional tuition subsidies. For instance, the federal TEACH Grant Program provides eligible students with a $4000 annual tuition grant provided they teach in high-needs schools and subject areas. Additionally, in the 1999-2000 school year, 24 states had conditional grant programs for new teachers (Ansell & McCabe, 2003). Many of these programs are conditional on serving some predetermined time in the public school system. Nonetheless, decisions about which students to target may affect their efficacy in recruiting new teachers and policymakers may be interested in retention beyond the first few years in the classroom.

Beyond the financial costs of replacing and training teachers, turnover may affect student achievement for at least two reasons. First, a common finding of the teacher effectiveness literature is that there are significant gains to experience during the first few years of a teacher's career (Clotfelter, Ladd, & Vigdor, 2007; Rockoff, 2004). To the extent that departing teachers are replaced with novices, higher levels of turnover could mechanically lower average teacher quality. However, the direction of the effect depends on the relationship between turnover and teacher effectiveness (Goldhaber et al., 2011). While teachers generally become more productive during the early part of their careers, there is substantial variation in teacher effectiveness within years of experience. Attrition of low-performing teachers has the potential to increase student achievement even if they are replaced by novices (Goldhaber & Hansen, 2010; Hanushek, 2009;

Staiger, & Rockoff, 2010). Second, the "churn" associated with teacher turnover may itself reduce student achievement. Ronfeldt, Loeb, & Wycokff (2012) argue that teacher turnover might disrupt instructional programs or impede efforts to develop collaborative networks of teachers within schools. They find that higher turnover reduces student achievement and that the turnover effect cannot be fully explained by the replacement of more senior teachers with novices. The effects of turnover appear to be especially harmful to students at high-needs schools.

Research on the correlates of teacher turnover suggests several reasons why it may vary across preparation programs. First, there is considerable variation in the characteristics of prospective teachers admitted to the preparation programs we consider and previous studies have linked teacher credentials, salary, and demographic characteristics to the likelihood of attrition (Clotfelter et al., 2011; Imazeki, 2005; Murnane & Olsen, 1989).[3] Differences in the characteristics of schools may also affect teacher mobility. The available evidence suggests that the proportion of minority students in a school is positively related to teacher attrition (Clotfelter, Ladd, & Vigdor, 2011; Imazeki, 2005; Murnane & Olsen, 1989; Scafidi, Sjoquist, & Stinebrickner, 2007).[4] The research is more conflicted on the role of poverty in teacher retention. Several studies have found no effect of poverty on teacher turnover when other school characteristics are included (Clotfelter et al., 2011; Imazeki, 2005; Murnane & Olsen, 1989). But

[3] There is mixed evidence on precisely which characteristics of teachers are related to mobility. Several studies have found that women are no more likely to exit the profession than men (Dolton & Van der Klaauw, 1995; Murnane & Olsen, 1990; Scafidi et al., 2007), but other results suggest that young women are more likely to exit (Clotfelter et al., 2011; Murnane & Olsen, 1989). There is also conflicting evidence on the effect of age on teacher attrition. Beyond finding higher exit rates for young women, Murnane & Olsen (1989) and Clotfelter et al. (2011) find little evidence that age relates to teacher attrition. However, Imazeki (2005) finds that older men are more likely to exit teaching. Several studies suggest minority teachers exit at higher rates (Clotfelter et al., 2011; Imazeki, 2005; Murnane & Olsen, 1989), but again, this finding is not universal (Goldhaber et al., 2011).

[4] Though evidence suggests that there is heterogeneity in this finding according to teachers' race/ethnicity, i.e. the finding mainly reflects the preferences of white teachers and does not hold for minority teachers (Imazeki, 2005; Scafidi et al., 2007).

other papers have found that higher poverty is associated with lower attrition, at least conditional on other school characteristics (Murnane & Olsen, 1990; Scafidi et al., 2007).

While some of the variation in mobility may be related to the selection of teachers to preparation programs or schools, programs may also be differentially effective in preparing their students for entering the teaching profession. DeAngelis, Wall, & Che (2013) find that teachers' satisfaction with their pre-service training is predictive of early career attrition. Ronfeldt, Schwarz, & Jacob (2013) document wide variation in the pre-service experiences of teachers and find that the amount of methods coursework and practice teaching are associated with lower attrition. Differences in the characteristics of schools in which teachers complete their pre-service internships may also affect retention (Ronfeldt, 2012). And Constantine et al. (2009) provide suggestive evidence that high-coursework preparation programs can improve novice teachers' classroom management skills. Graduates from more effective preparation programs may find the transition from student teaching to managing a classroom less difficult than their peers and, as a result, they may remain in the profession for a longer period of time.

The above discussion suggests that differences in teacher mobility across programs reflect a combination of the selection of prospective teachers for admission, the effects of exposure to a particular curriculum or faculty, and the sorting of teacher candidates to particular schools. While preparation programs may want to know what kinds of teacher training practices best prepare their students for the classroom, the effect on teachers of attending one or another preparation program is not the primary focus of this study. We instead focus on the overall differences in the probability of exiting either a teacher's current school or Washington State public schools altogether, including both selection into preparation programs as well as any human capital bestowed on teachers by programs themselves. However, it is important to note

how the framing of the problem limits the generalizability of our estimates of program effects. In particular, we are not explicitly modeling the effect on the probability of exiting the workforce of attending a particular preparation program. Rather, we are estimating contrasts in the rates of attrition across programs given the types of students those programs have historically trained.

Nonetheless, the total estimated differences in school mobility and attrition from the workforce are of policy interest for at least two reasons. First, differences in the rate at which teachers exit particular schools more closely reflects the information required by principals to assess a new candidate for a teaching position. Principals must make assessments of teacher candidates conditional on the observable information they have about potential teachers. Hence, the relevant consideration for a principal assessment is the likelihood of leaving the school given both the candidate selection and program effects of a particular preparation program. Given the effects of turnover on student outcomes, selecting teachers based on their propensity for mobility may be an important consideration for principals. Some survey evidence also suggests that principals value motivation and enthusiasm for teaching when considering new applicants and may consider these to be signals of the length of time a teacher will remain with the school (Harris, Rutledge, Ingle, & Thompson, 2010).[5] Moreover, the ability to predict a teacher's duration in teaching may be of particular interest given that the conventional indicators of teacher quality available at the time of hiring do not appear to explain much variation in the tenure of new teachers (Rockoff, Jacob, Kane, & Staiger, 2008). Second, state and federal policymakers have an interest in the overall levels of attrition from the state public school system given the financial costs of replacing departing teachers and the importance of early-career teaching experience on student achievement. The combined effect of selection and training may

[5] For instance, Harris et al. (2010) suggest that the findings of Ballou (1996), which argues that the teacher labor market does not appear to reward graduation from a selective university, can be partially explained by perceived differences in commitment to teaching or the likelihood of remaining in the profession.

also be the relevant regulatory consideration for policymakers and is the effect estimated by previous studies of program value-added (Henry et al., 2012). In Section VII, we consider how the effectiveness and mobility of teachers together influence the impacts of teacher preparation programs on student achievement.

III. Data

The data for this study come primarily from a collection of Washington State administrative databases. We derive teacher assignment data from the S-275, Washington State's school personnel reporting system, which is maintained by the Office of the Superintendent of Public Instruction (OSPI). School districts report each assignment for all their personnel at the beginning of October of each school year. Data on teacher licenses come from the Professional Educators Standards Board (PESB), which includes records on all teacher licenses issued in Washington State. We use the recommending agency of a teacher's first license as her training institution. The S-275 also includes demographic characteristics of teachers, including age, sex, ethnicity, and degree status.

The S-275 reports a teacher's final salary for all assignments in a given district. We sum this total over districts to determine the teacher's total salary for a given academic year. We deflate salaries to 2005 dollars using the Personal Consumption Expenditures (PCE) Core deflator for October of the reporting year. To account for cost-of-living differences across the state, we further deflate salaries using a Comparable Wage Index estimated using Census 1990 5% Sample, Census 2000 5% Sample, American Community Survey 2005 1% Sample, and American Community Survey 2010 1% Sample microdata and linear interpolation to impute values for the inter-Census years following the method of Taylor & Fowler (2006).[6]

[6] Results are similar if we do not adjust salaries for regional differences in the cost of living. For models with school random effects, regional variation in real wages has no effect. In general, for models without school random effects,

We obtain school-level data on teacher assignments using the Common Core of Data (CCD) for years 1989-1990 to 2011-2012.[7] The Washington State CCD files contain data on school type, school location, and school enrollments by grade level and ethnicity. For several of the years of our study, school-level data on free and reduced price lunch eligible students is unavailable. We also merge local unemployment data using the Bureau of Labor Statistics (BLS) local area unemployment series. For each year, we use the county unemployment rate in the year following the reporting year (i.e., the second calendar year of the school year) to reflect the job opportunities available when most attrition decisions are made.

We include all teachers who entered Washington public schools after the 1989-1990 school year in our analysis. We exclude teachers who entered before that time both to avoid left censoring and because the logical measure of elapsed duration, experience, does not actually measure years of work in the public school system in our data.[8] The S-275 survey asks districts to identify teachers with less than one-half year of experience as beginning teachers. We use this variable, as well as the reported years of experience and number of years reported in the data, to limit the sample to novice teachers. **Table 1** describes the final sample of teachers used in the analysis. It contains all first-time teachers entering in the 1989-1990 academic year through the 2010-2011 academic year. We observe 20,527 unique teachers and a total of 124,812 teacher-years.[9]

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omitting this adjustment results in slightly higher estimated attrition probabilities for programs located in the Seattle-Tacoma metropolitan area.

[7] Some teachers are linked to multiple buildings per year. To determine building assignments, we calculated the percentage of time spent in each building that corresponds to base contract, certificated assignments. If a teacher spent at least 50% of such time in one building, we coded her as assigned to that school. We dropped 2,876 observations for which we could not match a teacher to a building based on this criterion. We dropped a further 476 observations where the school code reported by the school districts did not match a valid school in the CCD. This represents about 2.6% of our sample.

[8] Teachers accumulate experience according to their full-time-equivalency (FTE), which may not correspond to calendar years worked.

[9] Counts of teachers in our sample by program and years of experience are presented in Appendix Table 1.

During the timespan we investigate, about 15.5 percent of teachers leave their current school per year; nearly half of these (about 7 percent) leave Washington State public schools. These figures are similar to nationwide turnover rates for teachers, although we observe fewer teachers leaving the workforce in Washington State (Keigher, 2010). Among first year teachers in our sample, 10.7% exit Washington Public Schools and 13.5% move to another school in the state. These attrition patterns are similar to those for recent novice teachers nationwide (Kaiser, 2011).

IV. The Market for New Teachers in Washington State

The PESB, the state's teacher credentialing body, recognizes twenty-one preparation programs in Washington State.[10] The preparation programs are located at public and private four-year universities around the state. The selectivity of these institutions varies greatly: the 75th percentile SAT score among incoming freshman ranges from 970 to 1340. In addition, a number of novice teachers graduate from preparation programs in other states. In our data, about 17% of novice teachers are from out-of-state programs.

Beyond selectivity, we identify several differences in the characteristics of teachers across preparation programs, which are reported in Panel A of **Table 2**.[11] For instance, while 70% of novice teachers in our sample are women, 81% and 85% of novice teachers from Northwest University and UW – Bothell, respectively, are women. Alumni of Antioch, Heritage, St. Martin's, UW – Bothell, and UW – Tacoma all tend to be older than average (all have average alumni ages over 30, while the mean among all teachers is 29.2 years). Differences in the offerings of various preparation programs are also reflected in substantial differences in the

[10] One of these programs first graduated new teachers in the 2009-2010 school year and, given this, is excluded from this study.

[11] To avoid confusion, we refer throughout the paper to schools of education as "preparation programs" or "programs" and to public primary and secondary schools as "schools."

educational attainment and endorsement areas of novice teachers. While 32% of new teachers hold an advanced degree, more than 70% of graduates of Antioch, City, Evergreen, Seattle, and Puget Sound have earned a master's degree before they start teaching.[12]

Differences in program offerings are also reflected in the assignments of novice teachers. In our entire sample, the mean percentage of time spent in a K-3 grade assignment is about 33%. However, graduates of Northwest and UW – Bothell average more than 50% of their time in K-3 assignments while graduates of Evergreen and Gonzaga average less than 25% time in elementary assignments. Finally, there are substantial differences in the possession of subject area endorsements. Among novice teachers, six percent hold an endorsement in English Language Learning (ELL), while five percent hold an endorsement in special education. Graduates of Heritage and St. Martin's are disproportionately likely to have earned an endorsement in ELL (25% and 10%, respectively) and graduates of Gonzaga, Pacific Lutheran, and Walla Walla are significantly more likely to have an endorsement in special education (15%, 13%, and 16%, respectively).

Research on the geography of teacher labor markets has consistently found that teachers tend to be employed near their hometowns or preparation programs (Boyd, Lankford, Loeb, & Wyckoff, 2005; Mihaly et al., 2012; Reininger, 2012). The market for novice teachers in Washington State reflects this fact, with teachers' first positions tending to be clustered around the location of their preparation programs. **Figure 1** shows this geographical dispersion by plotting the frequency of initial teacher placements by district for each preparation program. Teachers' initial placements are not as highly concentrated around their preparation programs as

[12] The proportion of novice teachers with advanced degrees masks considerable heterogeneity across cohorts and within teachers over time. Washington State has the second highest salary premium for advanced degrees in the country and, in recent years, more than 60 percent of our sample possesses an advanced degree. In 2007-2008, 64.2 percent of teachers in our sample had a master's degree, compared to 52.2 percent of traditional public school teachers nationwide (Coopersmith, 2009; Office of the Superintendent of Public Instruction, 2012).

they are around their high schools, but there is still clear evidence of clustering. While Reininger (2012) reports nearly 60% of teachers in the NELS:88 were working within 20 miles of their high school in 2000, we find that nearly one-third of in-state teachers take an initial teaching position within 20 miles of their preparation program.

Consistent with the geographical differences in placement by program, there are substantial differences in the characteristics of initial school placements. Panel B of Table 2 displays mean school characteristics for novice teachers. A few patterns are apparent. Several preparation programs are located in the state's largest three cities (Seattle, Spokane, and Tacoma) and send teachers disproportionately to urban schools with relatively high African American student enrollments. While the mean African American enrollment is 6%, the average African American enrollment for novice teachers from Antioch, Puget Sound, and UW – Tacoma all exceed 10 percent. Preparation programs located in the central and eastern parts of the state tend to send graduates to rural schools with higher Hispanic enrollment. The mean Hispanic enrollment for graduates of Central Washington, Heritage, and Walla Walla is 49 percent, 21 percent, and 30 percent, respectively, compared to a sample mean of 12 percent.

The last column of Panel B summarizes the differences in school characteristics among first-year teachers across programs. We estimate a probit regression of teacher attrition from Washington State Public Schools controlling for school characteristics and year fixed effects and estimate the probability of attrition predicted by the observables.[13] The mean predicted attrition probability is 0.075; however, some programs send graduates to schools with noticeably higher and lower predicted rates. Three programs send graduates to schools with predicted attrition

[13] We control for log enrollment, school demographic characteristics, school urbanicity, school level, distance to the nearest U.S. state border, school type, and local unemployment rate.

probabilities of at least 0.085 (Antioch, Seattle, and UW – Seattle), while two programs send graduates to schools with predicted attrition rates of less than 0.06 (Heritage and Walla Walla).

While the findings in Table 2 suggest teachers sort into schools based on observable school characteristics, we find this is also true when we examine within-school variation in student demographics. Previous research has found that teachers are sensitive to the demographic composition of the schools in which they teach (Boyd et al., 2007; Goldhaber, Gross, & Player, 2011; Hanushek et al., 2004; Jackson, 2009). We investigate this possibility in **Table 3** by regressing the share of schools' students in each of the three largest minority groups on the average demographic characteristics of the programs from which they hire teachers. That is, we examine whether changes in the demographic make-up of schools over time is correlated with changes in the types of programs from which they hire teachers. In Table 3, each column represents a regression of the school-level characteristic on the program characteristics of its current teachers. In the first three columns, we limit the sample to novice teachers. In the second three columns, we consider all teachers currently working in each school. We observe that changes in the composition of schools appear to be correlated with changes in staffing patterns although the coefficients are modest. For instance, as the share of African American students increases, schools hire more teachers from programs with high shares of African American prospective teachers. Overall, an increase in the average program share of African American teachers of 10% is correlated with an increase in the share of African American students of 3.8%.[14]

[14] In regressions not shown, we instead regress school demographic characteristics on teacher preparation program indicators and school and year fixed effects. In all regressions, except for when the dependent variable is the share of Hispanic students and the sample contains all teachers, we reject the null hypothesis that the program indicators are jointly zero at the 0.05 level. For the single exception, the program indicators are jointly significant at the 0.10 level.

Dynamic sorting of teachers to schools could result from many factors. Teachers may have preferences for the types of students they teach or they may be differentially effective with different types of students (Dee, 2005; Jackson, 2009; Loeb, Soland, & Fox, 2013). Alternatively, given the preference of teachers for taking positions near their hometowns, changes in the staffing of schools could reflect changes in geographic residency patterns (Boyd et al., 2005; Reininger, 2012). Whatever their cause, the dynamic patterns in Table 3 have implications both for our estimates and more broadly for analyses of preparation programs that use school fixed effects. To the extent that changes in student characteristics are associated with changes in unobservable factors affecting teacher mobility, estimates that rely on within-school variation in staffing to uncover the effects of preparation programs will be biased.[15] In our analyses of teacher attrition below, we explore this problem by estimating models with school-by-year effects. Our results suggest that changes in staffing over time may be correlated with other changes in student characteristics that influence student achievement and suggest caution when using school fixed effects in long panels.

V. Analytical Methods

We model teachers' first spell teaching in Washington state public schools using the binary outcome model

$$\Pr\left(Y_{ijst} = 1 \,\middle|\, T_i, S_{ijt}, s, t\right) = F(T_i\tau + S_{ijt}\beta + \lambda_s + \gamma_t + \epsilon_{ijst}) \qquad (2)$$

[15] This problem may not be limited to analyses of teacher attrition. Several previous studies that examine differences in teacher value-added by preparation programs have used school fixed effects to control for unobserved differences in student achievement among schools staffed by graduates of different preparation programs (Goldhaber et al., 2013; Koedel et al., 2012; Mihaly et al., 2012). However, note that these papers all consider panels of less than 5 years in which biases are likely to be minimal.

where Y is an indicator that the teacher exits the Washington public school system (or her school in some specifications) at the end of the school year,[16] T is an indicator for preparation program,[17] S is a vector of school and teacher assignment characteristics, γ_t is a year fixed effect, and λ_s is an experience fixed effect.[18] Our vector of assignment characteristics includes log salary, demographic characteristics of students in a school, county unemployment rate, school location, school level (middle, high, other non-elementary), and school type (alternative school, special education school, vocational education school). We also include an indicator for each of the first 10 years of experience and an indicator for more than 10 years of experience.

We limit our analyses to teachers' first spells in Washington Public Schools. In our sample about 13 percent of teachers have more than one spell in Washington Public Schools; however, this understates the true probability of re-entry given the right censoring of spells outside the school system. Therefore, we estimate Kaplan-Meier hazard models of the decision to return to teaching. Approximately 15 percent of exiting teachers will return to teaching after a one-year absence and 27 percent within 5 years.[19] The return of former teachers to the school system suggests that our results understate the total amount of time teachers remain in the profession.

Because turnover in the teacher labor market generally occurs at the end of each school year, we estimate (2) as a binary outcome model. Our specification estimates the hazard of

[16] Several studies have also examined attrition from a school district. Due to the fact that several programs have very low rates of mobility across school districts, we focus here on leaving the current school and exiting the state public school system.

[17] This specification implicitly assumes the effects of preparation programs on attrition are constant over time. In linear probability models, we find statistically significant differences in program effects on leaving the current building with school fixed effects for cohorts of teachers entering after 2000, but fail to reject the null hypothesis of no difference for leaving Washington Public Schools and with other specifications.

[18] Inclusion of experience fixed effects implicitly assumes that the effects of preparation programs are constant with respect to years of experience. We explore this assumption in Section V.3 below.

[19] The probabilities of re-entering the profession are broadly consistent with prior research on the subject (Beaudin, 1993; Grissom & Reininger, 2012; Stinebrickner, 2002). About 1 percent of the remaining teachers return to teaching in each of years 6-15 with very few returning thereafter.

attrition and accommodates right-censoring of labor market spells (Beck, Katz, & Tucker, 1998; Jenkins, 1995). Estimation of (2) is complicated by the fact that our outcome variable is dichotomous and that, in a number of specifications, we include school or school-by-year effects in *S*. Explicit estimation of nonlinear fixed effects using indicator variables is generally inconsistent, although the bias may be trivial when the number of observations per panel is large (Greene, 2002; Katz, 2001). This is frequently not the case in our models, particularly in those with school-by-year effects, where the number of teachers per cell is quite small for many schools.

One common solution is to model (2) as a conditional logit (Chamberlain, 1980; examples in the education literature include Boyd et al., 2006; 2007; Goldhaber et al., 2011). The benefit of this approach is that consistency does not require assumptions about the relationship between the school effects and the included covariates.[20] However, the fixed effects themselves are not estimated, which precludes estimation of the predicted probabilities and average marginal effects.[21] Given that one goal of the present study is to show how changes in the proportion of novice teachers graduating from different preparation programs might influence student outcomes, our analysis requires estimation of the predicted probabilities. Therefore, our preferred specification estimates a correlated random effects probit model (Wooldridge, 2010). We allow some dependence of the school effects on included regressors by including the school means of all the other variables in the model:

$$\Pr(Y_{ijst} = 1) = \Phi\left(T_i\tau + S_{ijt}\beta + \lambda_s + \gamma_t + \overline{T_i}\pi_1 + \overline{S_{ijt}}\pi_2 + \overline{\lambda_s}\pi_3 + \overline{\gamma_t}\pi_4 + \epsilon_{ijst}\right) \quad (3)$$

[20] It does, however, require a conditional independence assumption that rules out the sort of serial clustering typically found in panel data (Bertrand, Duflo, & Millainathan, 2004; Wooldridge, 2010).

[21] Some studies have proceeded by calculating marginal effects at the mean of the included covariates and plugging in values for the mean school effect (e.g., Boyd et al. 2006, 2007). Because there is substantial variation across programs in the characteristics of schools staffed by their graduates, we do not follow this approach here.

We estimate (3) as a pooled probit.[22] To allow for likely serial correlation in the error at the school level and the fact that the treatment of a preparation program is fixed within teachers, we adjust standard errors for arbitrary clustering at the school and teacher level (Cameron, Gelbach, & Miller, 2011; Koedel et al., 2012). Wooldridge (2010) observes that in the linear case, this model is equivalent to the fixed effects estimator and suggests that in the nonlinear case, the model may work reasonably well even when group effects are not independent of the regressors of interest. This appears to be the case in the present application: marginal effects estimated from the probit models are similar to the regression coefficients estimated by the corresponding linear fixed effects models and the odds ratios are very similar to those estimating by the corresponding conditional logit models.[23] While estimation of the model coefficients may rely on stronger assumptions than in the conditional logit case, estimation of average marginal effects and predicted probabilities is more straightforward because the means of the school coefficients provide a natural way to estimate the school-level heterogeneity.

Identification of the teacher preparation program effects in (2) and (3) requires that unobserved factors associated with teacher mobility are independent of the program indicators and other included covariates. There are several reasons why this might not be the case. Boyd et al. (2005) and Reininger (2012) emphasize the local nature of teacher labor markets with many teachers returning to schools near their hometown to teach. If teaching candidates also select into colleges near their hometown and there are unobserved local policies, such as mentoring or

[22] Because the number of teachers across schools is not uniform, Wooldridge (2010) recommends modeling the heteroskedasticity directly in the estimation of the probit model. Estimated probabilities and marginal effects are very similar between both methods, so we report the traditional pooled probit results here.

[23] We present a comparison of the three approaches in Appendix Tables 2-3. In particular, we calculate odds ratios as the exponential of the coefficients from the conditional logit models and marginal effects as the OLS coefficients from a linear probability model with fixed effects. We compare these with the marginal effects presented in Section V and, for the logit results, with the odds ratio predicted by the probit model for each observation averaged over all the observations linked to a particular preparation program. The estimates are quite close with the exception of a few of the smallest schools in our sample.

supplemental salaries, that are related to teacher retention, estimates based on school characteristics alone will provide biased estimates of preparation program effects. Within local labor markets, teachers from different programs may also systematically sort into schools in ways that bias the estimated coefficients. The substantial sorting on observable characteristics of teachers from different programs observed in Table 2 suggests that teachers may additionally sort along unobservable dimensions. These considerations suggest that specifications with school random effects may suffer less bias.

However, the literature on the effectiveness of teacher preparation programs has identified two areas of concern with using within-school comparisons. Mihaly et al. (2012) observe that if preparation programs staff mutually exclusive groups of schools, estimates derived from within-school comparisons are not directly comparable and preparation program effects may be conflated with differences in unobserved school effects across different groups of schools. Fortunately, despite the differences in geographical location apparent from Figure 1, nearly all the preparation programs in our sample are directly connected through common school assignments. Only two programs, UW – Bothell and Walla Walla, do not have a school (or school-by-year) assignment in common.

A second concern is whether teacher sorting through the labor market attenuates within-school variation in teacher tenure associated with preparation programs (Goldhaber et al., 2013; Mihaly et al., 2012). For instance, suppose that principals have different preferences for longevity (or a characteristic such as motivation or enthusiasm for teaching that is correlated with retention) and are able to predict it at the time of hire. If this is the case, then the teachers at a single school from different preparation programs may have similar attrition patterns even if there are differences across programs. Alternatively, teachers may have preferences for certain

kinds of assignments and sort into schools based on individual attributes associated with mobility. For instance, younger teachers in our sample are both more likely to leave the profession and more likely to take positions in elementary schools. If teachers from programs with large numbers of younger teachers serve disproportionately in schools with other young teachers, we may understate differences in attrition by examining within-school differences in mobility. We discuss this problem in Section VI.3 below.

VI. Results

We begin our discussion of results by reporting unconditional Kaplan-Meier survival rates for each of the programs. **Figure 2** plots the Kaplan-Meier survivor functions by program and documents wide variation in the persistence of teachers across preparation programs. Teachers credentialed outside the state are the most likely to exit the school system within 5 years (56% survival rate), while graduates of Heritage are most likely to remain in the school system (82% survival rate). Differences in persistence are also quite pronounced at 10 years, with 73% of Heritage graduates and 34% of Northwest graduates still teaching in Washington State.

VI.1 Teacher Preparation program Attrition Models

While informative, the differences in initial placement by program suggest school factors may influence the attrition decisions of teachers. In **Table 4**, we report the marginal effects of preparation programs in the probit model with and without school random effects. We compute the average marginal effects as the average difference in probability associated with a one unit increase in each of the program indicators across all observations associated with each preparation program. Because an indicator for out-of-state teachers is omitted from the model, marginal effects represent the average difference in probability associated with attending each of

the preparation programs over out-of-state teachers. We calculate standard errors using the delta method.

In columns (1)-(4) of **Table 4**, we display the results for models predicting the likelihood of exiting a school. Column (1) displays results with program, year, and experience indicators only and provides an unconditional look at differences in teacher mobility. The pattern of results is generally similar when covariates are added, although the results for some programs suggest sorting based on school assignments (columns 2 and 3). The estimated marginal effects with school random effects (column 3) range from 0.005 (Puget Sound) to -0.063 (Walla Walla). Graduates of the in-state programs are generally more likely to exit their school than out-of-state teachers. Alumni of Northwest (<0.001), Puget Sound (0.005), and Whitworth (0.003) are slightly more likely to change schools or leave the school system, although these estimates are not statistically significant. Graduates of the five largest programs, which together educate nearly 50 percent of new teachers in our sample, display similar rates of mobility (Western Washington, -0.031; Central Washington, -0.028; Eastern Washington, -0.032; Washington State, -0.031; UW – Seattle, -0.024).[24]

We report marginal effects for leaving Washington State Public Schools in columns (5)-(8). Differences in the rate at which teachers leave the public school system appear to explain much of the difference in mobility rates between in-state and out-of-state teachers, with graduates of in-state programs less likely to leave the profession. However, within the state, we observe a wide range in the likelihood of exiting the school system. As we report in Table 1, the sample average probability of leaving Washington schools is about 7 percent. Among the specifications with school random effects (column 7), the effects range from a high of -0.006

[24] We fail to reject the null hypothesis that the five largest programs have identical mobility rates at the 0.05 level for models in columns (2)-(4).

(Northwest) to a low of -0.05 (UW – Bothell). We also observe more variation among the five largest programs in the probability of exiting the school system than we do in the probability of exiting schools (Western Washington, -0.040; Central Washington, -0.041; Washington State, -0.032; Eastern Washington, -0.041; UW – Seattle, -0.025).[25]

For both outcomes, chi-square tests easily reject the null hypotheses that all programs have the same effects on mobility. Variation in attrition rates across programs appears to be both statistically and substantially important. The differences in the rate at which teachers exit their school and the public school system between the most and least mobile programs are approximately 40-50 percent of the average rates of mobility. However, we also estimate much smaller differences among the largest programs in our sample. In fact, we cannot distinguish statistically the effects of the largest five programs on the rate at which teachers leave their current school, although we can detect differences in the rate at which they leave the profession.

VI.2 Teacher Characteristics and Program Attrition

In section IV, we showed there are substantial differences in the characteristics of teachers and schools by teacher preparation programs. To explore how these characteristics affect unconditional differences in attrition rates across programs, we estimate models that include a number of teacher characteristics in addition to the controls included in previous models.

In **Table 5**, we decompose the contributions of individual teacher characteristics to the observed differences in attrition by program. We use the method suggested by Gelbach (2009), which exploits a sample analog of the (linear) omitted variables bias formula to identify the contributions of individual variables to a coefficient of interest. Because it relies on the

[25] We reject the null hypothesis that the five largest programs have identical mobility rates at the 0.01 level in all models.

parameters estimated from the full model that includes all covariates, it is not dependent on the order of variables considered, unlike more informal ways of characterizing the importance of individual groups of variables, such as adding them sequentially and displaying the intermediate results (Gelbach, 2009). We display the results in Table 5. In the first column, we display the coefficients from a linear probability model that includes school-by-year fixed effects. To show how salary influences the results, we exclude salary but the model is otherwise the OLS equivalent of column (8) of Table 4. The last column displays the coefficients from a model that includes several teacher covariates.

The second column of Table 5 documents the aggregate effect of differences in demographic characteristics, including gender, age, and race, on the estimated program effects. Differences in the age of teachers across programs generate most of the difference in program attrition rates attributed to demographic characteristics. As shown in Table 2, graduates of a few programs are substantially older, a characteristic that reduces the expected rate of attrition. In the third column, we display the effect of adding subject area endorsements and grade level assignments. In general, the effects of specialty area and grade level have little effect, at least when school-by-year effects are included.

The next two columns display the contribution of educational attainment and salary on relative program attrition rates. Table 2 indicates substantial differences in educational attainment by program, with some programs wholly or primarily educating prospective teachers through graduate programs. Washington has one of the highest salary premiums for advanced degrees in the country, and higher salaries are estimated to reduce attrition. Consequently, including salary in the model increases the estimates of attrition for graduates of programs that produce mostly graduate students, such as Antioch, City, Evergreen, Seattle, and Puget Sound.

Interestingly, however, conditional on salary, teachers with advanced degrees are actually more likely to leave the profession. Because most of the state is on a single salary schedule, higher salaries within years of experience typically correspond to having obtained master's degrees, so the higher average attrition rates attenuate the estimated effect of salaries in the baseline models.

Column (6) displays the total change in coefficients that results from adding teacher variables to the model. Six of the programs have coefficients in the model with teacher characteristics that are statistically significantly different than the baseline model. Four of these are programs with large shares of master's degree students and the resultant differences in salary appear to drive the results (Antioch, City, Evergreen, and UW – Seattle). Two other programs have changes that are associated with differences in the age of teacher candidates (UW – Bothell and UW - Tacoma). For the remaining programs, the differences in estimated coefficients that result from the additional teacher covariates are generally small and statistically insignificant. For instance, among the five largest programs, only UW – Seattle (0.004) has an absolute difference between the baseline and full model of greater than 0.002.

VI.3 Robustness Checks

The nonrandom process by which teachers find their initial job placements could bias our estimates of the differences in attrition rates by program. In sections IV and V, we discussed two mechanisms that could bias the coefficients estimated from models that rely on within-building variation. First, teachers appear to respond to changes in school demographics that may be correlated with changes in unobserved factors associated with teacher tenure. We test this possibility by estimating models with school-by-year random effects. Second, schools may select teachers for positions in such a way that comparisons that rely on within-school variation understate the true differences in teacher tenure across programs (Mihaly et al., 2012). In

addition to concerns about bias, another possibility is that models that measure the impact of preparation programs as constant across years of experience mask considerable heterogeneity in the timing of attrition.

Given that changes in staffing are correlated with changes in observable school characteristics that influence attrition, we additionally estimate model (2) with school-by-year random effects, which identify differences in attrition rates across programs by comparing teachers in the same school during the same academic year. Mihaly et al. (2012) observe that for such models to identify differences in outcomes across all programs in a state, it is necessary that preparation programs be connected directly or indirectly within schools. As noted above, we find that all the preparation programs in our sample are indirectly connected within school-by-year cells and only two programs (UW – Bothell and Walla Walla) are not directly connected. The results with school-by-year random effects are presented in columns (4) and (8) of Table 4. Estimated marginal effects are typically smaller when we include school-by-year effects. However, the program rankings are similar, which suggests the differences may be due to changes over time in the schools staffed by out-of-state teachers.[26]

Within-school comparisons of teacher outcomes may lead to misleading conclusions about teacher preparation programs if the teacher labor market leads to a hierarchical sorting of teachers to schools based on unobservable factors associated with teacher retention.[27] For instance, teachers that are more likely to remain in teaching may have preferences for similar kinds of schools and principals may be able to predict which candidates are most likely to remain

[26] The Spearman rank-order correlations of the marginal effects are 0.94 for exiting Washington Public Schools and 0.96 for leaving the current school.

[27] This may also be a problem in the estimation of program value-added models with school fixed effects (Goldhaber et al., 2013; Mihaly et al., 2012).

in the profession. In either case, this sort of matching of teachers to schools would weaken the within-school association between teacher preparation programs and attrition.

One indication that sorting across schools may not be a problem in this context is that the coefficients on preparation programs are of a similar magnitude with the inclusion of school random effects. Moreover, as the results in Table 5 demonstrate, the inclusion of several teacher variables associated with attrition has relatively little impact on most of the estimated program effects. Including salary, demographic characteristics, educational attainment, and subject endorsements changes the estimates of the five largest programs very little.[28] Moreover, the programs that are sensitive to the inclusion of teacher characteristics are primarily programs with large deviations from the average educational attainment, and hence salary, of novice teachers.

The research on teacher hiring also suggests that there may not be strong sorting across schools on unobserved dimensions. For instance, surveys of principal hiring decisions suggest that principals rely heavily teacher on observable credentials, such as licensure, experience, and degree type, and less on unobserved data, such as model lessons or teacher portfolios (Rutledge, Harris, Thompson, & Ingle, 2008). New hiring also often appears to occur at or after the beginning of the school year, which suggests principals may not have a significant number of applicants from which to choose (Jacob, 2007). Finally, while Rutledge et al. (2008) suggest principals place a great deal of weight on the interview, Rockoff et al. (2008) find little evidence of a relationship between personality traits or individual characteristics that might be observed in an interview and the probability that teachers remain in their schools.

The specifications in Table 4 assume a constant baseline hazard and a constant program effect. To test whether estimates of retention by program are sensitive to this assumption, we plot

[28] The estimated changes in the coefficients are: Western Washington (-0.001), Central Washington (-0.001), Washington State (-0.001), Eastern Washington (0.000), and UW – Seattle (0.004). Only the last is statistically significant.

the survivor functions estimated from the building-by-year random effects models against Kaplan-Meier survivor functions in Figure 2. In particular, we average the predicted probabilities over programs and years of experience and plot the results. In general, the curves estimated from the probit models match the Kaplan-Meier estimates fairly closely. The exceptions are primarily smaller programs, whose attrition patterns are estimated imprecisely, and programs such as Heritage and Walla Walla, which disproportionately serve special populations.

VII. Discussion

As we mentioned at the beginning of the paper, policymakers are increasingly interested in using outcome-based measures to evaluate teacher preparation programs. The U.S. Department of Education, for instance, recently proposed to base assessments of teacher preparation programs at least partially on value-added measures and to link eligibility for student loan or grant programs to the classroom performance of a preparation program's graduates (United States Department of Education, 2011). Additionally, 31 states included proposals to link student achievement outcomes to teacher preparation programs in their Race to the Top applications (Aldeman et al., 2011). The preceding results suggest the need for caution when basing assessments of teacher preparation programs solely on student achievement.

We use estimates of the program attrition and estimates of average teacher effectiveness by preparation program to illustrate this point. Our calculation is similar in spirit to Kane et al. (2008), which shows that even modest differences in average teacher effectiveness can outweigh large differences in teacher mobility. However, instead of estimating average teacher effectiveness by preparation program, we estimate the marginal effect on average student achievement of changes in the proportion of new teachers from each of the preparation programs. This effect is relevant for several of the reforms considered by the U.S. Department of

Education. The estimates of program effectiveness that account for attrition are generally smaller in magnitude than program estimates of value-added suggest because differences in measured teacher effectiveness across programs diminish over time and the most and least effective programs in the state have relatively high rates of attrition.[29]

We illustrate how programs influence student achievement inclusive of differences in mobility patterns by simulating the combined effects of differences in teacher effectiveness and attrition by program. However, this is an admittedly speculative exercise in that we make a number of simplifying assumptions in order to make the calculations tractable. First, let student achievement depend only on the average teacher quality of program graduates, τ, and the level of teacher turnover in a school, *to*:

$$A = \tau + \pi \times to + \epsilon \ . \tag{3}$$

Second, we assume that teachers are randomly assigned to schools so that the average school turnover is the state-level turnover rate. As in the empirical specification, we assume that the hazard is constant for teachers beyond their tenth year of experience. We also assume that all teachers who have not left the workforce beforehand retire after 30 years of experience.

Let teacher effectiveness depend on the preparation program attended and the length of time since the teacher completed the program (Goldhaber et al., 2013), so that

$$\tau_{pt} = \exp\{-\lambda t\}\gamma_p + r_t \ , \tag{4}$$

where t denotes experience, $\exp\{-\lambda t\}$ is the rate at which program effects decay, γ_p is the program effect, and r_t is the return to experience level t. Let n_p denote the proportion of entering

[29] For instance, the correlation between value-added and the marginal effect on exiting Washington Public Schools is 0.02, with a rank-order correlation of 0.13. Teachers from programs with more effective graduates are also less likely to return to teaching. We estimate rank-order correlations of -0.35 and -0.32 between the marginal program effects of returning to teaching and math and reading value-added, respectively.

teachers who have graduated from program p. Then the proportion of all teachers who have graduated from program p and are in experience year t is given by

$$n_{pt} = n_p \frac{\Pi_{s=1}^{t}(1-\theta_{js})}{\Sigma_{i=1}^{J} n_i \Sigma_{s=1}^{T}[\Pi_{u=1}^{s}(1-\theta_{iu})]}, \quad (5)$$

where θ_{pt} is the probability of exiting for a teacher who attended program p and who has experience t. Then the average effectiveness of all teachers is

$$\bar{\tau} = \Sigma_p \Sigma_t n_{pt}(\exp\{-\lambda t\}\gamma_p + r_t). \quad (6)$$

The turnover rate is

$$to = \Sigma_p \Sigma_t n_{pt} \theta_{pt}. \quad (7)$$

By assumption, this is the average school-level turnover rate. We assume that program effects have a decay parameter of -0.05, consistent with Goldhaber et al. (2013), and that the churn associated with teacher turnover reduces student achievement at a rate of -0.06 standard deviations, consistent with the results from Ronfeldt et al. (2011).

Now consider the effect of an incremental increase in the proportion of graduates from one of the teacher preparation programs and incremental decreases in the other programs proportional to their initial size. The effect on aggregate test scores is given by

$$\frac{\partial A}{\partial n_p} = \frac{\partial \bar{\tau}}{\partial n_p} + \pi \frac{\partial to}{\partial n_p} - \sum_{i \neq j} \frac{n_i}{1-n_j}\left(\frac{\partial \bar{\tau}}{\partial n_p} + \pi \frac{\partial to}{\partial n_p}\right). \quad (8)$$

That is, the effect depends on the marginal effect of a program's graduates and is offset by a weighted average of the effects of graduates of the other programs. In this simple model, increasing a program's attrition rate has three effects. First, there will be relatively fewer of the program's graduates in the workforce, so the program value-added estimate will receive less weight in the calculation of average teacher effectiveness. Second, overall attrition will increase and there will be relatively fewer experienced teachers in the workforce and lower average

teacher effectiveness. Third, increased turnover will reduce student achievement through the direct churn effect.

We present estimates of the overall effect of teacher preparation programs on student achievement in **Table 6**. Column (2) contains the estimates of the average program value-added. We display the marginal program effects on the probability of leaving Washington Public Schools in column (3) and on exiting the current school in column (4). In column (5), we estimate the marginal effect on student achievement of changes in the share of novice teachers from each of a preparation program's graduates ignoring any differences in attrition. These values differ from the results in column (1), which are mean differences between program graduates and out-of-state graduates.[30] Consider the most effective program in our sample, UW – Seattle. On average, students of teachers who graduated from UW – Seattle are anticipated to score about 0.047 standard deviations higher on Washington's state assessment than students of teachers from out of state (column 2). Moving from column (2) to column (5), we ignore attrition and only consider the marginal effect on achievement of an increase in the proportion of UW – Seattle graduates. Because 56.2% of novice teachers graduate from a program more effective than out-of-state teachers, if the share of UW – Seattle teachers is increased, with the share of teachers from other programs reduced proportionate to their existing shares, the marginal change

[30] The value-added analyses are based on student achievement in the 2005-06 to 2009-10 school years. The proctor of the state assessment was used as the teacher-student link for the data used for analysis for the 2005- 06 to 2008-09 school years. The assessment proctor is not intended to and does not necessarily identify the subject- matter teacher of a student. The "proctor name" might be another classroom teacher, teacher specialist, or administrator. We take additional measures to reduce the possibility of inaccurate matches by limiting our analyses to elementary school data where most students have only one primary teacher and only including matches where the listed proctor is reported (in the S-275) as being a certified teacher in the student's school and, further, where he or she is listed as 1.0 FTE in that school, as opposed to having appointments across various schools. And for the 2009-10 school year, we are able to check the accuracy of these proctor matches using the state's new Comprehensive Education Data and Research System (CEDARS) that matches students to teachers through a unique course ID. Our proctor match agrees with the student's teacher in the CEDARS system for about 95 percent of students in both math and reading.

in teacher effectiveness is 0.043, which is smaller than the estimated program value-added of 0.047.

In columns (6) and (7), we consider changes in the composition of the workforce that account for differences in mobility patterns. In column (6), we calculate the effect on student achievement considering only teacher attrition from the workforce. In column (7), we add the direct effects of turnover on student achievement. Both calculations use the specifications with school-by-year random effects. Again consider changing the share of teachers from UW – Seattle. The marginal effect ignoring attrition is 0.043 (column 5), but accounting for program effect decay, differences in retention, and the effects of turnover reduces the marginal effect of increasing the share of UW – Seattle graduates to 0.028 (column 7). Comparing columns (2), (5) and (7) for the other programs suggests that comparisons of mean value-added alone may inaccurately represent the marginal effect of increasing the share of graduates from the most effective programs.

Similarly, value-added comparisons overstate the gains to be had by reducing the share of the least effective programs because those programs tend also to have lower retention rates. The three least effective programs in our sample, Northwest, Evergreen, and Antioch, have program effects of -0.068, -0.065, and -0.051, respectively, but the marginal effects of reducing their shares of graduates are only 0.050, 0.052, and 0.042, respectively. An attempt to use program effectiveness as a screen for new teachers is further complicated by the fact that the least effective programs are also very small; for instance, our estimates suggest that were the least effective program eliminated (e.g. perhaps it loses accreditation), the direct effect would be to increase average student achievement only by 0.0003 standard deviations.[31]

[31] It is of course possible that this type of accountability might have indirect effects on other programs.

An important caveat is that our estimates apply to reforms aimed at changing the share of new teachers from a single state's preparation programs. Previous research has shown that more effective teachers tend to remain in the profession, so the relationship between program effectiveness and program retention we observe may not hold in other states (Boyd et al., 2007; Goldhaber et al., 2011). Moreover, some proposed reforms are aimed at improving the quality of low-performing preparation programs rather than reducing their share of the teacher workforce (Aldeman et al., 2011); our estimates do not speak to the ability of targeted grants to preparation programs to improve student achievement. Finally, an important goal of the targeted grant proposals is to incentivize innovations that would improve the quality of teacher training.

Nonetheless, while we document substantial variation in the retention patterns of teachers by preparation programs, these differences do not easily lend themselves to policies aimed at improving student achievement. In many states, combined state and federal subsidies to teacher training represent a sizable proportion of the total tuition for attending a preparation program. Policymakers at the state and federal level are increasingly interested in using their control over the financing of tuition to incent innovation in teacher education and improve selection into the training profession. Several states have begun analyzing the value-added of teachers from the various programs in their state. And while even modest differences in effectiveness across certification routes can offset large differences in attrition, because the programs with the highest attrition tend to be both the most and least effective programs, efforts to increase the share of graduates from effective institutions and reduce the share of graduates from ineffective institutions are likely to produce smaller than expected improvements in student achievement.

VIII. Conclusion

In this paper, we present some of the first evidence on differences in teacher labor supply across traditional teacher preparation programs. Consistent with the literature on the geography of teacher labor markets, we find strong evidence of geographic clustering by preparation program. We also find evidence that teachers from different programs sort into schools based on observable school characteristics and that changes in the demographic characteristics of schools predict changes in the staffing of teachers from particular preparation programs. If changes in observable school characteristics are additionally associated with changes in unobservable factors related to attrition or student achievement, our results suggest caution when using school fixed effects to identify differences across preparation programs. This problem may be particularly acute in long panels.

We also document substantial differences in mobility and rates of attrition associated with different preparation programs. While the average rate of mobility is about 15 percent per year in our sample, our estimates of the marginal effects of programs within a single state have a range of over five percentage points. However, much of the variation in teacher mobility is limited to smaller programs in our sample. While there is statistically significant variation in the rates at which teachers leave the public school system among the largest programs in the state, which collectively train nearly half of all new teachers, there is not statistically significant variation in the rate at which alumni of the largest programs exit their school.

Our findings are consistent with two broad themes that have emerged from the literature on teacher training and certification routes. Even modest differences in the average measured effectiveness across programs compensate for more substantial differences in attrition, a finding consistent with the literature on alternative certification and Teach for America (Boyd et al.,

2006; Kane et al., 2008). Yet there is substantially more variation in teacher effectiveness within programs than across them. We further find that the variation across programs in teacher effectiveness is attenuated when we consider the differential rates of teacher attrition. Our estimates do not consider the possibility that policymakers could improve the effectiveness of new teachers by improving the quality of teacher preparation programs (e.g., American Federation of Teachers, 2012) or changing the incentives for students to select into teaching (e.g., Aldeman et al., 2011). Nonetheless, we interpret our results as suggesting that proposed reforms of the teacher training pipeline that do not accomplish these objectives and instead result in re-sorting within existing teacher preparation pathways will have a limited effect on student achievement.

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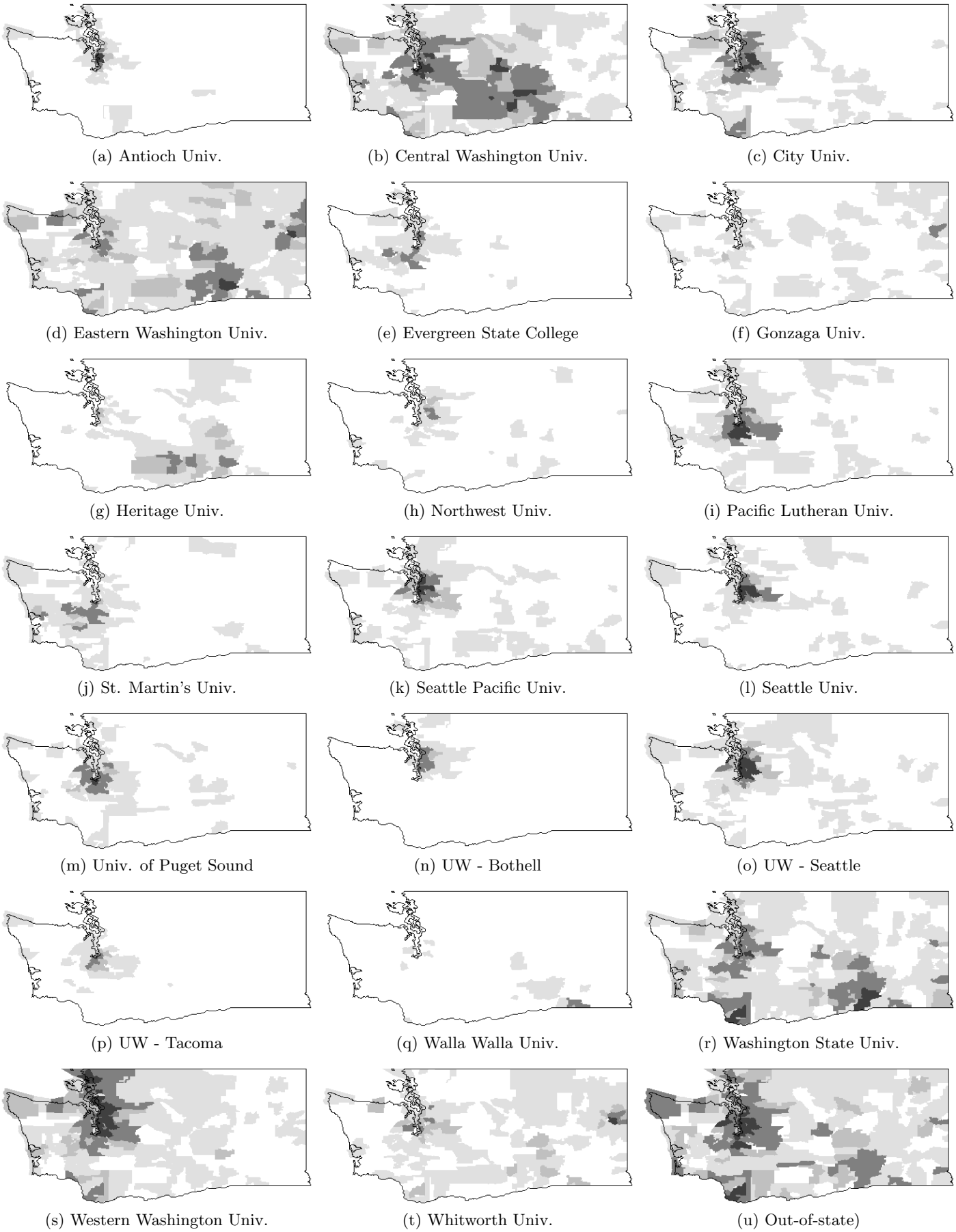
Figure 1: Initial Placement of Program Graduates by School District



(a) Antioch Univ. (b) Central Washington Univ. (c) City Univ.

(d) Eastern Washington Univ. (e) Evergreen State College (f) Gonzaga Univ.

(g) Heritage Univ. (h) Northwest Univ. (i) Pacific Lutheran Univ.

(j) St. Martin's Univ. (k) Seattle Pacific Univ. (l) Seattle Univ.

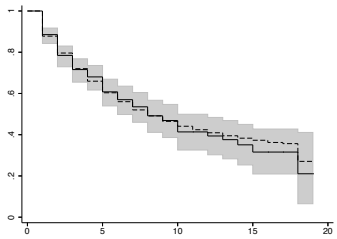
(m) Univ. of Puget Sound (n) UW - Bothell (o) UW - Seattle

(p) UW - Tacoma (q) Walla Walla Univ. (r) Washington State Univ.

(s) Western Washington Univ. (t) Whitworth Univ. (u) Out-of-state)

Key: ☐ 0 teachers, ■ 1-5 teachers, ■ 6-10 teachers, ■ 11-50 teachers, ■ 50+ teachers

Figure 2: Estimated Survivor Functions



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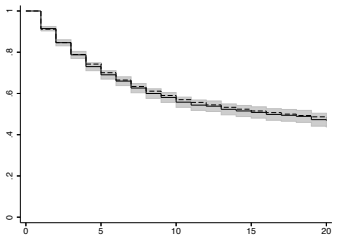

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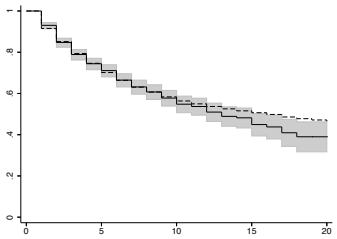

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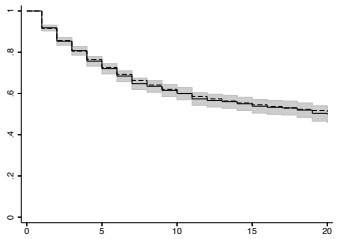

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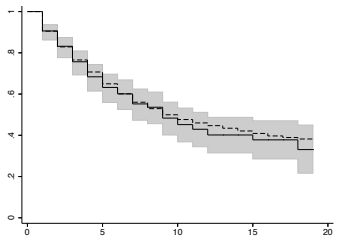

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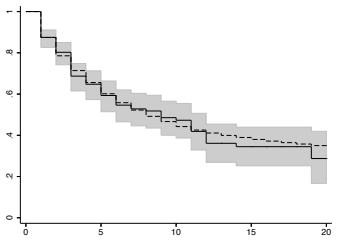

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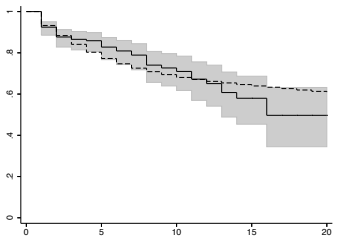

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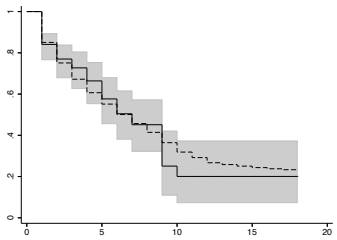

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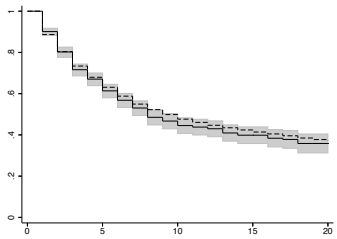
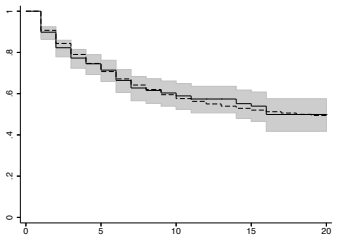


(i) Pacific Lutheran Univ.



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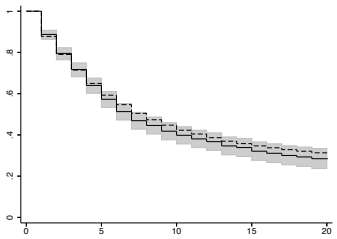

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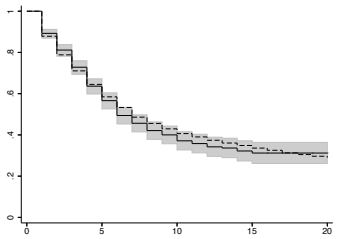

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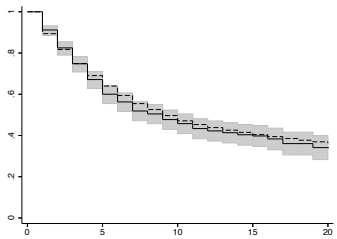

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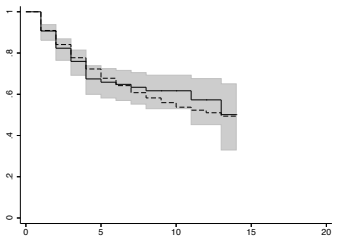

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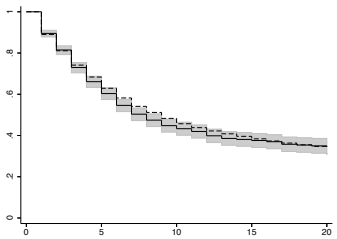

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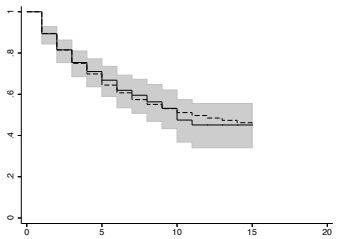

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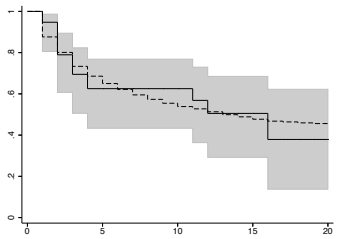

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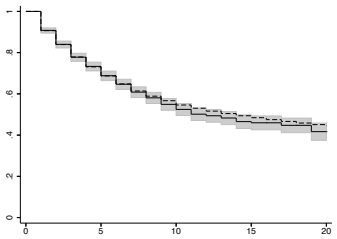

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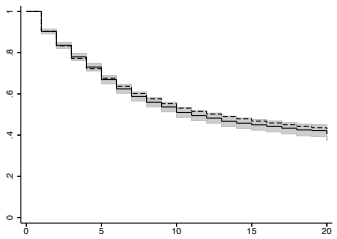

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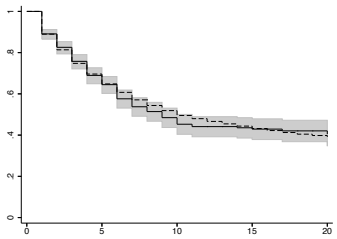
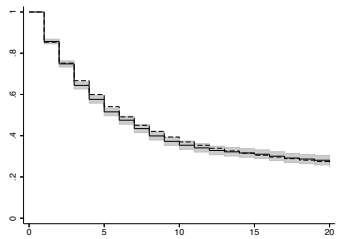


(t) Whitworth Univ.



(u) Out-of-state

x-axis: 0 —— 20	Kaplan-Meier Survivor Function ——
y-axis: 0 —— 1	Estimated Survivor Function - - - - -
	95% Confidence Interval (Kaplan-Meier)

(v) Legend

Table 1: Summary Statistics

	mean	sd
Exit WPS (%)	6.85	(25.26)
Move Schools (%)	15.50	(36.19)
Time in K-3 (%)	32.98	(45.91)
Time in 4-6 (%)	19.61	(37.51)
Time in 7-12 (%)	46.87	(48.83)
Total salary	43055.67	(12113.05)
Male (%)	33.54	(47.21)
Age	34.36	(8.66)
Years of experience	5.82	(4.66)
Eligible for pension (%)	0.21	(4.63)
Math endorsement (%)	10.95	(31.22)
Science endorsement (%)	12.90	(33.52)
English endorsement (%)	28.33	(45.06)
ELL endorsement (%)	6.21	(24.13)
Social studies endorsement (%)	26.56	(44.16)
Elementary endorsement (%)	59.19	(49.15)
Special education endorsement (%)	4.43	(20.58)
Health/PE endorsement (%)	8.92	(28.50)
Arts endorsement (%)	7.94	(27.04)
Foreign language endorsement (%)	6.71	(25.01)
Asian (%)	2.99	(17.04)
Black (%)	1.67	(12.83)
Hispanic (%)	2.55	(15.76)
American Indian (%)	0.61	(7.80)
Advanced degree (%)	52.94	(49.91)
School: American Indian Enrollment (%)	2.53	(5.97)
School: Asian Enrollment (%)	7.89	(8.03)
School: Enrollment Black (%)	5.16	(7.89)
School: Hispanic Enrollment (%)	11.88	(17.05)
School: Enrollment	761.31	(464.47)
County unemployment rate (%)	6.59	(2.25)
School location: city (%)	24.65	(43.10)
School location: suburb (%)	47.18	(49.92)
School location: town (%)	10.96	(31.24)
School location: rural (%)	17.21	(37.74)
School level: Elementary (%)	46.89	(49.90)
School level: Middle (%)	24.02	(42.72)
School level: High (%)	25.56	(43.62)
School level: Other (%)	3.54	(18.47)
School type: Regular (%)	98.64	(11.60)
School type: Special Ed. (%)	0.06	(2.50)
School type: Vocational (%)	0.00	(0.57)
School type: Alternative (%)	1.30	(11.32)
N	124812	

Notes: Salary deflated to 2005$ using Personal Consumption Expenditures index.

Table 2: Initial Teacher and School Characteristics by Program

Panel A: Teacher Characteristics

					Endorsements			
	Male	Age	Adv. Deg.	K-3	Math	Science	ELL	SPED
Antioch Univ.	31.3	34.1	72.8	31.7	10.7	15.4	1.1	1.1
Central Washington Univ.	32.2	28.1	4.3	40.2	10.3	8.1	8.1	7.9
City Univ.	33.1	32.4	81.9	44.1	6.0	6.2	1.0	1.6
Eastern Washington Univ.	38.0	28.4	9.0	29.6	10.8	11.6	2.7	3.3
Evergreen State College	30.8	32.3	96.4	21.1	12.1	20.2	5.7	2.8
Gonzaga Univ.	24.4	28.7	30.7	23.7	8.9	7.6	3.6	15.1
Heritage Univ.	25.3	34.3	27.7	40.8	9.5	10.7	24.5	2.4
Northwest Univ.	19.0	26.3	14.7	52.0	6.0	3.4	10.3	0.9
Pacific Lutheran Univ.	30.4	28.2	28.3	27.5	11.9	14.6	6.4	12.6
Univ. of Puget Sound	32.5	28.7	83.9	27.6	15.2	15.2	3.5	0.3
St. Martin's Univ.	28.2	33.7	12.3	32.9	18.2	18.7	10.3	4.7
Seattle Pacific Univ.	25.3	28.8	20.3	33.8	13.5	12.9	7.6	3.9
Seattle Univ.	25.1	29.8	92.4	28.8	7.7	14.8	6.2	1.4
UW - Bothell	15.2	33.8	13.5	54.6	9.9	9.4	1.8	0.4
UW - Seattle	28.8	29.8	56.4	29.6	10.3	19.0	8.2	5.1
UW - Tacoma	24.3	33.1	10.7	40.8	10.2	17.0	1.0	1.9
Walla Walla Univ.	21.6	28.5	10.8	47.3	5.4	10.8	0.0	16.2
Washington State Univ.	27.2	27.4	25.7	39.8	7.7	9.4	5.1	2.8
Whitworth Univ.	31.7	27.4	41.1	27.6	15.3	14.2	9.2	5.9
Western Washington Univ.	30.1	28.9	18.1	32.5	9.0	11.7	3.9	6.1
Out-of-state	31.2	29.0	30.7	27.2	12.7	12.8	5.8	3.2
Mean	30.2	29.2	32.4	33.1	10.6	12.1	5.8	4.7
N	20527	20527	20527	20527	20527	20527	20527	20527

Panel B: School Characteristics

	Enroll.	Black	Hisp.	City	Rural	Unemp. Rate	Border	Pr(Exit)
Antioch Univ.	720.3	15.0	10.3	50.7	5.1	5.2	107.9	8.6
Central Washington Univ.	685.7	4.3	21.0	19.6	21.6	7.1	79.1	7.1
City Univ.	612.6	7.6	8.9	22.0	13.1	5.9	86.3	7.2
Eastern Washington Univ.	692.2	3.0	15.1	29.3	26.1	7.0	54.0	6.9
Evergreen State College	796.4	8.6	7.8	23.1	12.6	6.4	74.6	7.4
Gonzaga Univ.	746.5	4.4	9.0	36.4	20.0	6.5	54.0	6.9
Heritage Univ.	659.5	2.8	49.4	24.5	24.5	8.4	52.8	5.8
Northwest Univ.	689.0	4.0	10.1	18.1	15.5	6.2	103.2	7.1
Pacific Lutheran Univ.	796.8	8.6	7.1	20.8	10.8	6.0	82.0	7.7
Univ. of Puget Sound	818.2	10.4	6.8	33.3	9.0	6.0	84.8	8.1
St. Martin's Univ.	695.7	6.4	6.3	17.3	22.3	6.8	63.6	7.2
Seattle Pacific Univ.	772.8	6.9	7.3	32.5	8.1	5.6	106.5	8.3
Seattle Univ.	823.6	8.9	7.8	32.3	7.9	5.5	106.4	8.5
UW - Bothell	551.8	4.6	9.1	25.1	4.9	5.7	118.7	7.1
UW - Seattle	789.4	8.0	7.3	33.9	5.1	5.4	107.0	8.5
UW - Tacoma	648.0	13.1	9.9	26.7	9.7	6.3	81.0	7.3
Walla Walla Univ.	635.2	2.4	30.4	16.2	16.2	6.7	24.4	5.7
Washington State Univ.	706.3	3.7	15.2	27.0	19.3	6.7	54.5	6.5
Whitworth Univ.	767.5	3.7	10.4	30.8	25.2	6.7	54.1	6.8
Western Washington Univ.	745.1	4.4	7.7	23.0	17.7	5.9	115.6	7.9
Out-of-state	788.5	5.9	9.7	27.4	17.9	6.4	77.3	7.6
Mean	737.9	5.8	11.7	26.5	16.5	632.2	83.2	7.5
N	20527	20527	20527	20527	20527	20527	20527	20527

Notes: Mean teacher characteristic by program for first-year teachers. Grades K-3 denotes the proportion of time spent in teaching assignments in grades K-3. Pr(Exit) denotes estimated probability of a teacher leaving Washington Public Schools given observable school characteristics.

Table 3: Within-school Changes in Student Demographics and the Characteristics of Teachers' Preparation Programs

	Novice Teachers			All Teachers		
	Pct. Asian	Pct. Black	Pct. Hisp	Pct. Asian	Pct. Black	Pct. Hisp
Percent Asian Teachers	-0.060**	0.016	0.035	-0.156**	0.019	0.082
	(0.030)	(0.025)	(0.033)	(0.068)	(0.047)	(0.081)
Percent Black Teachers	0.039	0.120***	-0.155*	0.079	0.375***	-0.217
	(0.053)	(0.045)	(0.080)	(0.135)	(0.101)	(0.190)
Percent Hispanic Teachers	-0.035**	-0.017	0.047	-0.095***	-0.060***	0.285***
	(0.014)	(0.011)	(0.042)	(0.030)	(0.023)	(0.095)
Percent Teachers with Adv. Deg.	-0.001	-0.005*	0.005	0.004	-0.012**	0.007
	(0.003)	(0.002)	(0.004)	(0.007)	(0.005)	(0.009)
N	13328	13328	13328	32107	32107	32107

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors clustered by training program in parantheses.

Table 4: Estimated Teacher Training Program Attrition Effects (Marginal Effects)

	Exit Building				Exit Wash. Public Schools			
Program Name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Antioch Univ.	-0.020*	-0.036***	-0.030***	-0.028**	-0.019***	-0.024***	-0.033***	-0.028***
	(0.010)	(0.011)	(0.012)	(0.013)	(0.007)	(0.008)	(0.008)	(0.010)
Central Washington	-0.021***	-0.028***	-0.028***	-0.030***	-0.039***	-0.040***	-0.041***	-0.041***
	(0.004)	(0.004)	(0.005)	(0.005)	(0.003)	(0.003)	(0.003)	(0.004)
City Univ.	-0.022***	-0.020***	-0.019***	-0.020***	-0.041***	-0.032***	-0.032***	-0.030***
	(0.006)	(0.006)	(0.006)	(0.007)	(0.004)	(0.004)	(0.004)	(0.005)
Eastern Washington	-0.038***	-0.034***	-0.032***	-0.030***	-0.042***	-0.036***	-0.041***	-0.036***
	(0.005)	(0.005)	(0.005)	(0.006)	(0.003)	(0.003)	(0.004)	(0.004)
Evergreen State College	-0.014	-0.005	-0.012	-0.017	-0.028***	-0.016**	-0.022**	-0.023**
	(0.013)	(0.013)	(0.015)	(0.014)	(0.008)	(0.007)	(0.009)	(0.009)
Gonzaga Univ.	-0.015	-0.007	-0.011	-0.000	-0.017**	-0.009	-0.016*	-0.014
	(0.011)	(0.011)	(0.012)	(0.014)	(0.008)	(0.008)	(0.009)	(0.010)
Heritage Univ.	-0.062***	-0.068***	-0.060***	-0.057***	-0.057***	-0.047***	-0.046***	-0.044***
	(0.011)	(0.011)	(0.012)	(0.012)	(0.005)	(0.006)	(0.007)	(0.008)
Northwest Univ.	0.016	0.002	-0.000	0.002	0.006	-0.008	-0.006	-0.012
	(0.020)	(0.020)	(0.022)	(0.023)	(0.016)	(0.016)	(0.017)	(0.019)
Pacific Lutheran Univ.	-0.010*	-0.014**	-0.015**	-0.019***	-0.023***	-0.024***	-0.022***	-0.023***
	(0.006)	(0.006)	(0.007)	(0.007)	(0.004)	(0.004)	(0.004)	(0.005)
St. Martin's Univ.	-0.029***	-0.027***	-0.031***	-0.026***	-0.040***	-0.036***	-0.039***	-0.036***
	(0.008)	(0.008)	(0.009)	(0.010)	(0.005)	(0.005)	(0.006)	(0.007)
Seattle Pacific Univ.	-0.011*	-0.022***	-0.021***	-0.020***	-0.013***	-0.024***	-0.026***	-0.023***
	(0.006)	(0.006)	(0.007)	(0.007)	(0.005)	(0.005)	(0.005)	(0.006)
Seattle Univ.	-0.008	-0.011	-0.008	-0.006	-0.011**	-0.016***	-0.017***	-0.014**
	(0.007)	(0.007)	(0.007)	(0.008)	(0.005)	(0.005)	(0.006)	(0.006)
Univ. of Puget Sound	0.002	0.006	0.005	0.002	-0.023***	-0.016***	-0.013***	-0.010*
	(0.007)	(0.007)	(0.007)	(0.008)	(0.005)	(0.004)	(0.005)	(0.005)
UW - Bothell	-0.035***	-0.049***	-0.045***	-0.057***	-0.038***	-0.047***	-0.050***	-0.051***
	(0.012)	(0.013)	(0.014)	(0.016)	(0.009)	(0.009)	(0.010)	(0.011)
UW - Seattle	-0.024***	-0.026***	-0.024***	-0.025***	-0.020***	-0.023***	-0.025***	-0.024***
	(0.005)	(0.005)	(0.005)	(0.006)	(0.004)	(0.004)	(0.004)	(0.004)
UW - Tacoma	-0.019	-0.033***	-0.040***	-0.039***	-0.033***	-0.031***	-0.034***	-0.030***
	(0.013)	(0.013)	(0.014)	(0.015)	(0.009)	(0.009)	(0.010)	(0.011)
Walla Walla Univ.	-0.051**	-0.032	-0.063***	-0.059***	-0.029*	-0.009	-0.032	-0.038*
	(0.025)	(0.023)	(0.022)	(0.020)	(0.017)	(0.017)	(0.020)	(0.020)
Washington State Univ.	-0.031***	-0.028***	-0.029***	-0.032***	-0.036***	-0.030***	-0.032***	-0.031***
	(0.004)	(0.004)	(0.005)	(0.005)	(0.003)	(0.003)	(0.003)	(0.004)
Western Washington	-0.025***	-0.032***	-0.031***	-0.033***	-0.033***	-0.040***	-0.040***	-0.036***
	(0.004)	(0.004)	(0.004)	(0.005)	(0.003)	(0.003)	(0.003)	(0.004)
Whitworth Univ.	-0.013*	-0.001	0.003	0.005	-0.026***	-0.014***	-0.015***	-0.012**
	(0.007)	(0.007)	(0.008)	(0.008)	(0.005)	(0.005)	(0.005)	(0.006)
School char	N	Y	Y	N	N	Y	Y	N
School RE	N	N	Y	N	N	N	Y	N
School-by-year RE	N	N	N	Y	N	N	N	Y
χ^2 test of all programs	141.833	168.751	142.142	136.341	386.964	358.974	328.021	264.330
χ^2 test of WA programs	132.454	147.622	125.268	120.626	371.761	309.574	285.725	230.479
N	124812	124812	124812	124812	124812	124812	124812	124812

Notes: Results in columns (1) and (5) include program, year, and experience indicators only. Specifications in columns (2)-(4) and (6)-(8) add log salary, school characteristics, school random effects, and school-by-year random effects. The χ^2 test of all programs tests the joint significance of the program coefficients in the original probit model. Standard errors of the marginal effects are calculated by the delta method and clustered by teacher and school ($*$, $p < 0.10$; $**$, $p < 0.05$; $***$, $p < 0.01$.).

Table 5: Contribution of Teacher Characteristics to Differences in Program Attrition Rates

Program Name	Baseline Model	Effect of Adding Variables					Full Model
		Demog.	Assignment	Adv. Deg.	Salary	Total	
Antioch Univ.	-0.032	0.003	0.003	-0.005	0.008	0.008***	-0.024
Central Washington Univ.	-0.039	0.000	0.001	0.002	-0.004	-0.001	-0.040
City Univ.	-0.041	0.005	0.003	-0.005	0.009	0.012***	-0.029
Eastern Washington Univ.	-0.039	-0.000	0.001	0.001	-0.002	0.000	-0.038
Evergreen State College	-0.036	0.002	-0.002	-0.006	0.011	0.006**	-0.030
Gonzaga Univ.	-0.016	-0.001	0.001	0.000	0.000	0.000	-0.016
Heritage Univ.	-0.049	0.002	0.002	-0.001	-0.001	0.003	-0.046
Northwest Univ.	0.002	0.001	0.001	0.003	-0.008	-0.003	-0.001
Pacific Lutheran Univ.	-0.024	0.000	0.001	-0.000	-0.000	0.000	-0.023
St. Martin's Univ.	-0.036	0.002	0.001	0.002	-0.002	0.003	-0.034
Seattle Pacific Univ.	-0.020	-0.000	0.000	0.001	-0.003	-0.002	-0.022
Seattle Univ.s	-0.019	0.000	-0.001	-0.006	0.007	0.001	-0.019
Univ. of Puget Sound	-0.023	0.000	-0.002	-0.005	0.010	0.003	-0.019
UW - Bothell	-0.045	0.004	0.001	0.003	-0.001	0.008***	-0.037
UW - Seattle	-0.031	0.001	-0.002	-0.002	0.007	0.004***	-0.027
UW - Tacoma	-0.030	0.005	0.002	0.003	0.000	0.010***	-0.020
Walla Walla Univ.	-0.033	-0.002	0.001	0.002	-0.008	-0.008	-0.041
Washington State Univ.	-0.032	-0.001	0.001	0.000	-0.001	-0.001	-0.033
Western Washington Univ.	-0.036	0.000	-0.000	0.001	-0.002	-0.001	-0.037
Whitworth Univ.	-0.019	-0.002	-0.000	-0.001	0.002	-0.001	-0.020

$* \; p < 0.10$, $** \; p < 0.05$, $*** \; p < 0.01$

Notes: Estimates derived from linear probability models using the decomposition described in the text (Gelbach, 2009). Baseline model includes program, experience, year, and school-by-year fixed effects. Full model additionally includes teacher demographic characteristics (sex, age in five-year increments, race, pension eligibility), assignment characteristics (percentage time in grades K-3 and 4-6, subject endorsement areas), advanced degree status, and log salary.

Table 6: Marginal Effects on Average Achievement of Increasing Share of Graduates

	(1) Size	(2) VA	(3) EX	(4) TO	(5) ME_{VA}	(6) ME_{EX}	(7) ME_{TO}
Antioch Univ.	1.3%	-0.051	-0.028	-0.028	-0.058	-0.041	-0.041
Central Washington Univ.	12.5%	-0.005	-0.041	-0.030	-0.014	-0.011	-0.011
City Univ.	5.4%	-0.007	-0.030	-0.020	-0.014	-0.011	-0.012
Eastern Washington Univ.	7.3%	0.003	-0.036	-0.030	-0.004	-0.003	-0.002
Evergreen State College	1.2%	-0.065	-0.023	-0.017	-0.073	-0.051	-0.052
Gonzaga Univ.	1.1%	0.046	-0.014	-0.000	0.039	0.024	0.023
Heritage Univ.	1.2%	0.011	-0.044	-0.057	0.004	0.004	0.006
Northwest Univ.	0.6%	-0.068	-0.012	0.002	-0.076	-0.049	-0.050
Pacific Lutheran Univ.	5.3%	0.022	-0.023	-0.019	0.016	0.010	0.009
St. Martin's Univ.	1.7%	-0.033	-0.036	-0.026	-0.041	-0.032	-0.031
Seattle Pacific Univ.	3.8%	0.016	-0.023	-0.020	0.010	0.005	0.005
Seattle Univ.	3.9%	-0.005	-0.014	-0.006	-0.012	-0.009	-0.011
Univ. of Puget Sound	2.8%	0.039	-0.010	0.002	0.033	0.019	0.018
UW - Bothell	1.1%	0.023	-0.051	-0.057	0.016	0.013	0.014
UW - Seattle	6.7%	0.047	-0.024	-0.025	0.043	0.029	0.029
UW - Tacoma	1.0%	0.031	-0.030	-0.039	0.025	0.017	0.017
Walla Walla Univ.	0.2%	0.011	-0.038	-0.059	0.004	0.003	0.005
Washington State Univ.	9.5%	0.006	-0.031	-0.032	-0.001	-0.001	-0.001
Western Washington Univ.	12.9%	0.009	-0.036	-0.033	0.003	0.002	0.002
Whitworth Univ.	3.2%	0.038	-0.012	0.005	0.032	0.019	0.018

Notes: Marginal effects on student achievement are calculated as described in the text. Size represents the share of novice teachers in the sample who graduated from each program. VA represents the estimated program value-added from Goldhaber et al. (2013). Column 3 (EX) displays the estimated marginal effect of exiting Washington Public Schools estimated in column 3 of Table 4. Column 4 (TO) displays the estimated marginal effects of exiting a teacher's current school shown in column 6 of Table 4. ME_{VA} represents the marginal effect on average teacher quality of an increase in the share of graduates from the given program, ignoring turnover and teacher attrition. ME_{EX} calculates the marginal effect on average teacher quality accounting for program effect decay and teacher attrition. We assume program effects decay at a rate of $\exp\{-0.05t\}$, consistent with decay parameters estimated in Goldhaber et al. (2013). ME_{TO} estimates the marginal effect on student achievement of changes in the share of teachers from each training program additionally accounting for the effects of turnover on student achievement. We assume that a one-unit increase in average turnover reduces student achievement by 0.06 standard deviations, consistent with the results of Ronfeldt et al. (2011).

Table A-1: Teacher Counts by Program and Year of Experience

Program Name	1	2	3	4	5	6	7	8	9	10	11
Antioch Univ.	272	213	182	155	125	89	71	52	45	34	25
Central Washington Univ.	2561	2049	1778	1502	1250	1079	924	784	689	600	518
City Univ.	1103	942	805	688	569	468	366	299	241	205	157
Eastern Washington Univ.	1496	1258	1111	994	867	767	671	585	534	472	423
Evergreen State College	247	202	174	149	115	93	84	75	64	49	41
Gonzaga Univ.	225	170	143	111	95	81	65	58	53	43	37
Heritage Univ.	253	195	161	132	118	95	83	68	56	46	40
Northwest Univ.	116	74	59	48	40	33	20	13	10	5	4
Northwest Univ.	3532	2699	2217	1782	1472	1191	1002	850	721	604	494
Pacific Lutheran Univ.	1084	880	739	621	517	425	347	300	254	224	195
St. Martin's Univ.	358	283	237	206	176	161	129	110	103	91	81
Seattle Pacific Univ.	778	639	545	457	384	321	265	223	204	175	147
Seattle Univ.	806	648	545	455	362	292	225	181	148	117	86
Seattle Univ.	223	174	136	115	86	65	47	38	29	24	15
Seattle Univ.	1382	1138	990	840	717	610	498	431	372	318	272
Seattle Univ.	206	161	139	108	88	70	53	40	36	27	20
Univ. of Puget Sound	579	495	431	371	309	259	227	193	174	152	137
Walla Walla Univ.	37	31	24	18	16	16	15	14	12	12	11
Washington State Univ.	1958	1604	1396	1172	974	807	674	555	477	395	325
Western Washington Univ.	2651	2195	1919	1681	1454	1231	1062	903	795	688	587
Whitworth Univ.	660	522	462	383	328	281	230	195	166	141	118
Total	20527	16572	14193	11988	10062	8434	7058	5967	5183	4422	3733

Table A-2: Estimated Probit Coefficients (Exit School)

	(1)	(2)	(3)	(4)	(5)	(6)
Antioch Univ.	-0.140	-0.132	-0.139	-0.096	-0.111	-0.102
	(0.045)	(0.045)	(0.042)	(0.042)	(0.053)	(0.053)
Central Washington Univ.	-0.119	-0.109	-0.091	-0.095	-0.129	-0.115
	(0.018)	(0.018)	(0.018)	(0.018)	(0.020)	(0.021)
City Univ.	-0.083	-0.067	-0.113	-0.053	-0.084	-0.070
	(0.025)	(0.026)	(0.023)	(0.024)	(0.027)	(0.028)
Eastern Washington Univ.	-0.157	-0.156	-0.130	-0.137	-0.143	-0.139
	(0.022)	(0.022)	(0.022)	(0.022)	(0.025)	(0.026)
Evergreen State College	-0.018	-0.052	-0.099	-0.072	-0.067	-0.099
	(0.053)	(0.053)	(0.050)	(0.052)	(0.056)	(0.056)
Gonzaga Univ.	-0.030	-0.048	-0.039	-0.051	-0.001	-0.012
	(0.045)	(0.046)	(0.046)	(0.047)	(0.056)	(0.057)
Heritage Univ.	-0.308	-0.284	-0.250	-0.227	-0.266	-0.245
	(0.055)	(0.056)	(0.051)	(0.051)	(0.056)	(0.057)
Northwest Univ.	0.006	0.017	0.025	0.013	0.009	0.030
	(0.072)	(0.071)	(0.071)	(0.071)	(0.085)	(0.084)
Pacific Lutheran Univ.	-0.058	-0.063	-0.057	-0.055	-0.077	-0.073
	(0.024)	(0.024)	(0.024)	(0.024)	(0.028)	(0.028)
St. Martin's Univ.	-0.119	-0.098	-0.118	-0.100	-0.116	-0.090
	(0.037)	(0.037)	(0.037)	(0.038)	(0.043)	(0.043)
Seattle Pacific Univ.	-0.087	-0.091	-0.064	-0.078	-0.083	-0.087
	(0.027)	(0.027)	(0.025)	(0.026)	(0.030)	(0.030)
Seattle Univ.	-0.042	-0.077	-0.059	-0.057	-0.024	-0.063
	(0.027)	(0.028)	(0.025)	(0.026)	(0.031)	(0.032)
Univ. of Puget Sound	0.025	-0.007	-0.023	-0.015	0.008	-0.029
	(0.028)	(0.028)	(0.025)	(0.026)	(0.030)	(0.030)
UW - Bothell	-0.193	-0.143	-0.159	-0.111	-0.225	-0.173
	(0.053)	(0.054)	(0.051)	(0.052)	(0.063)	(0.064)
UW - Seattle	-0.110	-0.129	-0.120	-0.106	-0.107	-0.124
	(0.021)	(0.022)	(0.020)	(0.021)	(0.024)	(0.025)
UW - Tacoma	-0.126	-0.084	-0.148	-0.096	-0.148	-0.101
	(0.051)	(0.051)	(0.050)	(0.050)	(0.058)	(0.058)
Walla Walla Univ.	-0.156	-0.148	-0.243	-0.271	-0.279	-0.280
	(0.123)	(0.129)	(0.112)	(0.108)	(0.107)	(0.108)
Washington State Univ.	-0.120	-0.125	-0.108	-0.118	-0.137	-0.142
	(0.019)	(0.019)	(0.018)	(0.018)	(0.021)	(0.021)
Western Washington Univ.	-0.137	-0.133	-0.115	-0.115	-0.140	-0.136
	(0.018)	(0.018)	(0.017)	(0.017)	(0.020)	(0.020)
Whitworth Univ.	-0.003	-0.032	0.003	-0.013	0.020	-0.008
	(0.028)	(0.029)	(0.029)	(0.029)	(0.035)	(0.036)
Exp=1	-0.149	-0.147	-0.147	-0.115	-0.136	-0.134
	(0.015)	(0.015)	(0.014)	(0.014)	(0.018)	(0.018)
Exp=2	-0.192	-0.188	-0.194	-0.136	-0.186	-0.183
	(0.017)	(0.017)	(0.015)	(0.016)	(0.020)	(0.020)
Exp=3	-0.231	-0.228	-0.242	-0.160	-0.220	-0.217
	(0.018)	(0.018)	(0.017)	(0.017)	(0.022)	(0.022)
Exp=4	-0.240	-0.235	-0.257	-0.155	-0.234	-0.232
	(0.020)	(0.020)	(0.018)	(0.019)	(0.024)	(0.024)
Exp=5	-0.214	-0.205	-0.243	-0.118	-0.192	-0.190
	(0.021)	(0.022)	(0.019)	(0.020)	(0.025)	(0.026)
Exp=6	-0.272	-0.258	-0.298	-0.155	-0.247	-0.242
	(0.023)	(0.024)	(0.020)	(0.022)	(0.026)	(0.028)
Teacher chars	N	Y	N	Y	N	Y
School RE	N	N	Y	Y	N	N
School-by-year RE	N	N	N	N	Y	Y

Continued on next page.

Table A-2 (Exit School) – continued from previous page.

	(1)	(2)	(3)	(4)	(5)	(6)
Exp=7	-0.335	-0.316	-0.368	-0.199	-0.285	-0.276
	(0.026)	(0.027)	(0.023)	(0.024)	(0.029)	(0.030)
Exp=8	-0.316	-0.290	-0.367	-0.176	-0.294	-0.278
	(0.027)	(0.029)	(0.024)	(0.027)	(0.032)	(0.033)
Exp=9	-0.374	-0.342	-0.433	-0.214	-0.330	-0.304
	(0.030)	(0.031)	(0.027)	(0.029)	(0.034)	(0.035)
Exp≥10	-0.458	-0.395	-0.561	-0.248	-0.406	-0.346
	(0.022)	(0.025)	(0.019)	(0.024)	(0.025)	(0.028)
Prop. American Indian Students	0.268	0.306	0.566	0.702		
	(0.086)	(0.090)	(0.394)	(0.399)		
Prop. Asian Students	-0.155	-0.170	-0.400	-0.430		
	(0.089)	(0.089)	(0.180)	(0.179)		
Prop. Black Students	0.453	0.489	0.110	0.040		
	(0.082)	(0.084)	(0.231)	(0.231)		
Prop. Hispanic Students	0.024	0.041	-0.060	-0.041		
	(0.039)	(0.040)	(0.123)	(0.123)		
Log Enrollment	-0.071	-0.070	0.114	0.123		
	(0.022)	(0.022)	(0.037)	(0.037)		
Log Enrollment x Middle School	-0.013	-0.031	0.013	0.010		
	(0.037)	(0.037)	(0.010)	(0.010)		
Log Enrollment x High School	-0.005	-0.020	0.006	0.002		
	(0.027)	(0.028)	(0.014)	(0.013)		
Log Enrollment x Other Configuration	0.041	0.021	0.015	0.010		
	(0.032)	(0.032)	(0.010)	(0.010)		
County Unemployment Rate	0.013	0.014	0.009	0.016		
	(0.004)	(0.004)	(0.006)	(0.006)		
Location: City	0.012	0.019				
	(0.015)	(0.015)				
Location: Town	-0.045	-0.040				
	(0.020)	(0.020)				
Location: Rural	-0.019	-0.014				
	(0.017)	(0.017)				
Middle School	0.181	0.163				
	(0.235)	(0.236)				
High School	0.087	0.020				
	(0.177)	(0.181)				
Other Configuration	-0.160	-0.156				
	(0.198)	(0.197)				
Special Education School	0.538	0.570				
	(0.084)	(0.087)				
Alternative School	0.064	0.048				
	(0.056)	(0.057)				
Distance to Nearest State Border	0.001	0.001				
	(0.000)	(0.000)				
District is off state salary schedule	-0.016	-0.011				
	(0.018)	(0.018)				
Prop. time in K-3		-0.171		-0.211		-0.221
		(0.027)		(0.028)		(0.033)
Prop. time in 4-6		-0.037		-0.077		-0.048
		(0.025)		(0.024)		(0.029)
Male		-0.049		-0.048		-0.052
		(0.011)		(0.010)		(0.012)
Age: 30-34		-0.019		-0.019		-0.005
		(0.013)		(0.012)		(0.014)
Teacher chars	N	Y	N	Y	N	Y
School RE	N	N	Y	Y	N	N
School-by-year RE	N	N	N	N	Y	Y

Continued on next page.

Table A-2 (Exit School) – continued from previous page.

	(1)	(2)	(3)	(4)	(5)	(6)
Age: 35-39		-0.069		-0.065		-0.060
		(0.017)		(0.016)		(0.019)
Age: 40-44		-0.151		-0.135		-0.140
		(0.019)		(0.018)		(0.021)
Age: 45+		-0.141		-0.129		-0.125
		(0.018)		(0.017)		(0.020)
Pension Eligible		0.343		0.334		0.339
		(0.100)		(0.092)		(0.116)
Endorsement: Math		0.051		0.054		0.056
		(0.017)		(0.016)		(0.018)
Endorsement: Science		0.054		0.060		0.067
		(0.015)		(0.014)		(0.017)
Endorsement: English		0.030		0.031		0.027
		(0.012)		(0.011)		(0.013)
Endorsement: English Language Learning		0.025		0.012		0.025
		(0.020)		(0.018)		(0.022)
Endorsement: Social Studies		0.023		0.024		0.029
		(0.012)		(0.011)		(0.013)
Endorsement: Elementary		-0.016		-0.033		-0.032
		(0.017)		(0.015)		(0.018)
Endorsement: Special Education		0.027		0.034		0.038
		(0.024)		(0.023)		(0.028)
Endorsement: Health		-0.020		-0.002		-0.002
		(0.018)		(0.017)		(0.019)
Endorsement: Arts		0.096		0.087		0.084
		(0.019)		(0.018)		(0.021)
Endorsement: Foreign Languages		0.079		0.081		0.083
		(0.020)		(0.019)		(0.022)
Asian		0.002		0.002		0.013
		(0.029)		(0.026)		(0.029)
Black		0.014		0.031		0.030
		(0.037)		(0.033)		(0.040)
Hispanic		-0.043		-0.047		-0.057
		(0.031)		(0.029)		(0.033)
American Indian		0.051		0.052		0.106
		(0.065)		(0.058)		(0.068)
Advanced Degree		0.058		0.060		0.070
		(0.012)		(0.012)		(0.014)
Year=1990	-0.054	-0.028	0.012	-0.094		
	(0.057)	(0.057)	(0.061)	(0.062)		
Year=1991	-0.116	-0.093	-0.058	-0.148		
	(0.044)	(0.044)	(0.048)	(0.048)		
Year=1992	-0.119	-0.097	-0.058	-0.165		
	(0.041)	(0.042)	(0.043)	(0.044)		
Year=1993	-0.037	-0.020	0.000	-0.083		
	(0.038)	(0.039)	(0.041)	(0.042)		
Year=1994	-0.062	-0.050	-0.019	-0.109		
	(0.036)	(0.037)	(0.040)	(0.041)		
Year=1995	-0.165	-0.157	-0.099	-0.202		
	(0.035)	(0.036)	(0.039)	(0.040)		
Year=1996	-0.063	-0.058	-0.022	-0.110		
	(0.034)	(0.035)	(0.040)	(0.040)		
Year=1997	0.028	0.032	0.060	-0.030		
	(0.038)	(0.038)	(0.044)	(0.044)		
Teacher chars	N	Y	N	Y	N	Y
School RE	N	N	Y	Y	N	N
School-by-year RE	N	N	N	N	Y	Y

Continued on next page.

Table A-2 (Exit School) – continued from previous page.

	(1)	(2)	(3)	(4)	(5)	(6)
Year=1998	0.032	0.032	0.055	-0.021		
	(0.036)	(0.037)	(0.042)	(0.042)		
Year=1999	0.062	0.062	0.095	0.010		
	(0.035)	(0.035)	(0.041)	(0.041)		
Year=2000	0.150	0.157	0.148	0.104		
	(0.036)	(0.036)	(0.041)	(0.041)		
Year=2001	0.100	0.104	0.102	0.058		
	(0.031)	(0.031)	(0.034)	(0.034)		
Year=2002	-0.008	-0.004	-0.001	-0.039		
	(0.029)	(0.030)	(0.031)	(0.031)		
Year=2003	-0.015	-0.009	-0.019	-0.045		
	(0.033)	(0.033)	(0.033)	(0.033)		
Year=2004	0.040	0.047	0.030	0.018		
	(0.031)	(0.031)	(0.033)	(0.033)		
Year=2005	0.053	0.062	0.045	0.039		
	(0.033)	(0.033)	(0.037)	(0.037)		
Year=2006	0.091	0.104	0.080	0.086		
	(0.034)	(0.034)	(0.039)	(0.039)		
Year=2007	0.119	0.133	0.102	0.121		
	(0.036)	(0.036)	(0.041)	(0.041)		
Year=2008	0.028	0.042	0.012	0.043		
	(0.033)	(0.033)	(0.036)	(0.036)		
Year=2009	-0.030	-0.015	-0.045	-0.016		
	(0.029)	(0.029)	(0.027)	(0.028)		
Year=2010	-0.096	-0.084	-0.093	-0.083		
	(0.032)	(0.032)	(0.030)	(0.030)		
N	124812	124812	124812	124812	124812	124812
Teacher chars	N	Y	N	Y	N	Y
School RE	N	N	Y	Y	N	N
School-by-year RE	N	N	N	N	Y	Y

Table A-3: Estimated Probit Coefficients (Exit Washington Public Schools)

	(1)	(2)	(3)	(4)	(5)	(6)
Antioch Univ.	-0.142	-0.115	-0.192	-0.168	-0.166	-0.147
	(0.048)	(0.049)	(0.053)	(0.054)	(0.060)	(0.061)
Central Washington Univ.	-0.309	-0.292	-0.313	-0.295	-0.311	-0.293
	(0.023)	(0.023)	(0.025)	(0.025)	(0.026)	(0.027)
City Univ.	-0.235	-0.192	-0.240	-0.194	-0.226	-0.188
	(0.029)	(0.031)	(0.031)	(0.033)	(0.035)	(0.036)
Eastern Washington Univ.	-0.302	-0.285	-0.340	-0.326	-0.308	-0.290
	(0.026)	(0.027)	(0.031)	(0.031)	(0.033)	(0.034)
Evergreen State College	-0.110	-0.139	-0.150	-0.177	-0.157	-0.188
	(0.056)	(0.058)	(0.062)	(0.064)	(0.066)	(0.068)
Gonzaga Univ.	-0.060	-0.058	-0.104	-0.105	-0.095	-0.089
	(0.053)	(0.054)	(0.061)	(0.062)	(0.066)	(0.067)
Heritage Univ.	-0.409	-0.374	-0.406	-0.365	-0.387	-0.349
	(0.060)	(0.060)	(0.068)	(0.067)	(0.074)	(0.074)
Northwest Univ.	-0.043	-0.022	-0.034	-0.013	-0.062	-0.036
	(0.085)	(0.083)	(0.095)	(0.092)	(0.097)	(0.097)
Pacific Lutheran Univ.	-0.164	-0.158	-0.153	-0.143	-0.156	-0.145
	(0.028)	(0.028)	(0.031)	(0.032)	(0.033)	(0.034)
St. Martin's Univ.	-0.281	-0.243	-0.302	-0.260	-0.280	-0.242
	(0.046)	(0.047)	(0.050)	(0.052)	(0.054)	(0.055)
Seattle Pacific Univ.	-0.152	-0.147	-0.164	-0.161	-0.143	-0.141
	(0.031)	(0.031)	(0.034)	(0.034)	(0.036)	(0.036)
Seattle Univ.	-0.096	-0.125	-0.102	-0.135	-0.081	-0.116
	(0.032)	(0.033)	(0.035)	(0.035)	(0.038)	(0.039)
Univ. of Puget Sound	-0.118	-0.144	-0.094	-0.128	-0.076	-0.109
	(0.033)	(0.034)	(0.036)	(0.037)	(0.039)	(0.040)
UW - Bothell	-0.299	-0.242	-0.317	-0.256	-0.322	-0.268
	(0.068)	(0.067)	(0.071)	(0.070)	(0.072)	(0.072)
UW - Seattle	-0.155	-0.172	-0.170	-0.188	-0.160	-0.177
	(0.025)	(0.025)	(0.027)	(0.028)	(0.029)	(0.030)
UW - Tacoma	-0.201	-0.130	-0.216	-0.140	-0.196	-0.123
	(0.062)	(0.063)	(0.069)	(0.070)	(0.074)	(0.076)
Walla Walla Univ.	-0.074	-0.068	-0.246	-0.244	-0.280	-0.288
	(0.148)	(0.148)	(0.163)	(0.162)	(0.153)	(0.150)
Washington State Univ.	-0.225	-0.222	-0.241	-0.240	-0.228	-0.227
	(0.024)	(0.024)	(0.026)	(0.026)	(0.028)	(0.028)
Western Washington Univ.	-0.282	-0.275	-0.285	-0.278	-0.262	-0.257
	(0.022)	(0.022)	(0.023)	(0.023)	(0.024)	(0.024)
Whitworth Univ.	-0.105	-0.120	-0.114	-0.134	-0.091	-0.110
	(0.035)	(0.035)	(0.038)	(0.038)	(0.042)	(0.042)
Exp=1	-0.075	-0.075	-0.055	-0.056	-0.054	-0.055
	(0.018)	(0.018)	(0.018)	(0.018)	(0.021)	(0.021)
Exp=2	-0.065	-0.063	-0.031	-0.029	-0.048	-0.048
	(0.020)	(0.020)	(0.020)	(0.020)	(0.023)	(0.023)
Exp=3	-0.099	-0.098	-0.053	-0.051	-0.070	-0.072
	(0.021)	(0.021)	(0.022)	(0.022)	(0.026)	(0.026)
Exp=4	-0.089	-0.086	-0.031	-0.028	-0.059	-0.062
	(0.023)	(0.023)	(0.023)	(0.024)	(0.027)	(0.028)
Exp=5	-0.107	-0.102	-0.042	-0.038	-0.074	-0.077
	(0.026)	(0.026)	(0.026)	(0.027)	(0.030)	(0.031)
Exp=6	-0.134	-0.127	-0.061	-0.056	-0.111	-0.114
	(0.027)	(0.029)	(0.028)	(0.029)	(0.031)	(0.033)
Teacher chars	N	Y	N	Y	N	Y
School RE	N	N	Y	Y	N	N
School-by-year RE	N	N	N	N	Y	Y

Continued on next page.

Table A-3 (Exit Washington Public Schools) – continued from previous page.

	(1)	(2)	(3)	(4)	(5)	(6)
Exp=7	-0.235	-0.221	-0.154	-0.142	-0.174	-0.172
	(0.032)	(0.034)	(0.033)	(0.035)	(0.036)	(0.038)
Exp=8	-0.233	-0.210	-0.143	-0.122	-0.195	-0.186
	(0.035)	(0.037)	(0.036)	(0.038)	(0.041)	(0.043)
Exp=9	-0.220	-0.185	-0.127	-0.094	-0.158	-0.133
	(0.037)	(0.038)	(0.037)	(0.039)	(0.042)	(0.044)
Exp≥10	-0.333	-0.254	-0.230	-0.154	-0.274	-0.200
	(0.026)	(0.031)	(0.028)	(0.033)	(0.031)	(0.035)
Log Salary	-0.855	-0.823	-0.925	-0.900	-0.923	-0.902
	(0.027)	(0.029)	(0.030)	(0.032)	(0.034)	(0.037)
Prop. American Indian Students	0.161	0.195	0.670	0.696		
	(0.099)	(0.105)	(0.517)	(0.513)		
Prop. Asian Students	0.185	0.175	-0.136	-0.116		
	(0.098)	(0.097)	(0.240)	(0.240)		
Prop. Black Students	0.115	0.161	-0.339	-0.339		
	(0.091)	(0.094)	(0.311)	(0.312)		
Prop. Hispanic Students	-0.136	-0.116	-0.319	-0.309		
	(0.047)	(0.047)	(0.170)	(0.169)		
Log Enrollment	-0.031	-0.031	0.011	0.019		
	(0.026)	(0.026)	(0.041)	(0.041)		
Log Enrollment x Middle School	-0.023	-0.045	0.010	0.009		
	(0.040)	(0.040)	(0.012)	(0.012)		
Log Enrollment x High School	-0.018	-0.034	0.018	0.016		
	(0.032)	(0.032)	(0.018)	(0.018)		
Log Enrollment x Other Configuration	-0.006	-0.023	0.026	0.024		
	(0.043)	(0.045)	(0.013)	(0.013)		
County Unemployment Rate	0.022	0.023	0.032	0.031		
	(0.005)	(0.005)	(0.008)	(0.008)		
Location: City	0.032	0.039				
	(0.016)	(0.016)				
Location: Town	0.004	0.013				
	(0.025)	(0.025)				
Location: Rural	-0.008	0.002				
	(0.019)	(0.019)				
Middle School	0.248	0.313				
	(0.257)	(0.253)				
High School	0.286	0.282				
	(0.207)	(0.210)				
Other Configuration	0.219	0.250				
	(0.266)	(0.277)				
Special Education School	-0.061	-0.055				
	(0.167)	(0.171)				
Alternative School	-0.109	-0.109				
	(0.059)	(0.059)				
Distance to Nearest State Border	0.001	0.001				
	(0.000)	(0.000)				
District is off state salary schedule	0.023	0.025				
	(0.018)	(0.018)				
Prop. time in K-3		-0.097		-0.095		-0.083
		(0.032)		(0.038)		(0.042)
Prop. time in 4-6		-0.036		-0.047		-0.009
		(0.028)		(0.033)		(0.037)
Male		-0.137		-0.144		-0.143
		(0.014)		(0.015)		(0.016)
Teacher chars	N	Y	N	Y	N	Y
School RE	N	N	Y	Y	N	N
School-by-year RE	N	N	N	N	Y	Y

Continued on next page.

Table A-3 (Exit Washington Public Schools) – continued from previous page.

	(1)	(2)	(3)	(4)	(5)	(6)
Age: 30-34		0.023		0.020		0.037
		(0.016)		(0.017)		(0.019)
Age: 35-39		-0.115		-0.114		-0.120
		(0.021)		(0.023)		(0.025)
Age: 40-44		-0.203		-0.197		-0.187
		(0.025)		(0.026)		(0.028)
Age: 45+		-0.113		-0.119		-0.091
		(0.022)		(0.024)		(0.026)
Pension Eligible		0.811		0.820		0.636
		(0.109)		(0.111)		(0.127)
Endorsement: Math		0.007		0.012		0.009
		(0.020)		(0.021)		(0.022)
Endorsement: Science		0.043		0.047		0.053
		(0.019)		(0.020)		(0.021)
Endorsement: English		-0.003		0.003		-0.002
		(0.015)		(0.016)		(0.017)
Endorsement: English Language Learning		-0.006		-0.011		-0.017
		(0.024)		(0.025)		(0.027)
Endorsement: Social Studies		-0.004		0.006		0.014
		(0.015)		(0.015)		(0.017)
Endorsement: Elementary		-0.060		-0.073		-0.060
		(0.020)		(0.022)		(0.024)
Endorsement: Special Education		0.009		0.025		0.016
		(0.030)		(0.032)		(0.035)
Endorsement: Health		-0.122		-0.110		-0.112
		(0.024)		(0.025)		(0.026)
Endorsement: Arts		0.109		0.110		0.103
		(0.022)		(0.024)		(0.025)
Endorsement: Foreign Languages		0.061		0.063		0.052
		(0.024)		(0.026)		(0.028)
Asian		0.042		0.054		0.039
		(0.030)		(0.033)		(0.035)
Black		0.007		-0.004		0.025
		(0.045)		(0.047)		(0.051)
Hispanic		-0.040		-0.048		-0.071
		(0.037)		(0.040)		(0.043)
American Indian		0.069		0.048		0.054
		(0.073)		(0.078)		(0.081)
Advanced Degree		0.048		0.060		0.056
		(0.014)		(0.015)		(0.017)
Year=1990	-0.213	-0.143	-0.249	-0.185		
	(0.068)	(0.069)	(0.079)	(0.079)		
Year=1991	-0.117	-0.052	-0.150	-0.089		
	(0.052)	(0.052)	(0.061)	(0.062)		
Year=1992	-0.249	-0.187	-0.292	-0.235		
	(0.050)	(0.051)	(0.057)	(0.058)		
Year=1993	-0.174	-0.117	-0.206	-0.154		
	(0.045)	(0.046)	(0.053)	(0.053)		
Year=1994	-0.162	-0.109	-0.191	-0.144		
	(0.044)	(0.045)	(0.052)	(0.053)		
Year=1995	-0.165	-0.114	-0.195	-0.152		
	(0.043)	(0.044)	(0.052)	(0.052)		
Year=1996	-0.140	-0.095	-0.159	-0.123		
	(0.041)	(0.042)	(0.052)	(0.052)		
Teacher chars	N	Y	N	Y	N	Y
School RE	N	N	Y	Y	N	N
School-by-year RE	N	N	N	N	Y	Y

Continued on next page.

Table A-3 (Exit Washington Public Schools) – continued from previous page.

	(1)	(2)	(3)	(4)	(5)	(6)
Year=1997	-0.092	-0.050	-0.112	-0.082		
	(0.043)	(0.044)	(0.055)	(0.055)		
Year=1998	0.033	0.071	0.028	0.056		
	(0.043)	(0.044)	(0.054)	(0.054)		
Year=1999	0.018	0.056	0.009	0.036		
	(0.041)	(0.042)	(0.053)	(0.053)		
Year=2000	0.112	0.147	0.106	0.130		
	(0.041)	(0.042)	(0.051)	(0.051)		
Year=2001	0.082	0.113	0.067	0.089		
	(0.037)	(0.038)	(0.045)	(0.045)		
Year=2002	0.039	0.066	0.017	0.038		
	(0.036)	(0.037)	(0.041)	(0.041)		
Year=2003	-0.009	0.017	-0.026	-0.007		
	(0.038)	(0.038)	(0.041)	(0.042)		
Year=2004	0.031	0.055	0.033	0.050		
	(0.037)	(0.038)	(0.043)	(0.044)		
Year=2005	0.039	0.066	0.055	0.073		
	(0.040)	(0.040)	(0.048)	(0.048)		
Year=2006	0.092	0.122	0.111	0.133		
	(0.041)	(0.042)	(0.051)	(0.051)		
Year=2007	0.086	0.113	0.119	0.137		
	(0.043)	(0.044)	(0.052)	(0.053)		
Year=2008	0.048	0.071	0.073	0.090		
	(0.040)	(0.040)	(0.047)	(0.047)		
Year=2009	-0.033	-0.014	-0.040	-0.021		
	(0.035)	(0.035)	(0.036)	(0.036)		
Year=2010	-0.165	-0.159	-0.176	-0.170		
	(0.038)	(0.039)	(0.039)	(0.039)		
N	124812	124812	124812	124812	124812	124812
Teacher chars	N	Y	N	Y	N	Y
School RE	N	N	Y	Y	N	N
School-by-year RE	N	N	N	N	Y	Y

Table A-4: Comparison of Probit to Other Specifications (Exit School)

	Odds Ratios				Marginal Effects			
Program Name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Antioch Univ.	0.806	0.808	0.821	0.837	-0.030	-0.031	-0.028	-0.026
Central Washington Univ.	0.803	0.808	0.792	0.786	-0.028	-0.029	-0.030	-0.030
City Univ.	0.867	0.867	0.860	0.852	-0.019	-0.020	-0.020	-0.021
Eastern Washington Univ.	0.750	0.761	0.766	0.759	-0.032	-0.035	-0.030	-0.032
Evergreen State College	0.916	0.908	0.886	0.889	-0.012	-0.015	-0.017	-0.018
Gonzaga Univ.	0.920	0.907	0.999	0.983	-0.011	-0.014	-0.000	-0.003
Heritage Univ.	0.592	0.592	0.612	0.593	-0.060	-0.064	-0.057	-0.058
Northwest Univ.	0.999	0.996	1.013	0.984	-0.000	0.002	0.002	0.005
Pacific Lutheran Univ.	0.891	0.894	0.872	0.868	-0.015	-0.015	-0.019	-0.018
St. Martin's Univ.	0.778	0.781	0.809	0.803	-0.031	-0.033	-0.026	-0.028
Seattle Pacific Univ.	0.857	0.862	0.862	0.857	-0.021	-0.021	-0.020	-0.020
Seattle Univ.s	0.946	0.956	0.958	0.965	-0.008	-0.008	-0.006	-0.006
Univ. of Puget Sound	1.038	1.039	1.015	1.026	0.005	0.004	0.002	0.001
UW - Bothell	0.723	0.727	0.672	0.650	-0.045	-0.044	-0.057	-0.053
UW - Seattle	0.825	0.833	0.823	0.820	-0.024	-0.025	-0.025	-0.025
UW - Tacoma	0.760	0.753	0.771	0.744	-0.040	-0.039	-0.039	-0.036
Walla Walla Univ.	0.559	0.566	0.597	0.565	-0.063	-0.066	-0.059	-0.062
Washington State Univ.	0.790	0.798	0.780	0.777	-0.029	-0.031	-0.032	-0.031
Western Washington Univ.	0.783	0.787	0.776	0.769	-0.031	-0.032	-0.033	-0.033
Whitworth Univ.	1.027	1.031	1.039	1.040	0.003	0.001	0.005	0.003
Specification	Probit	Logit	Probit	Logit	Probit	OLS	Probit	OLS
School Fixed/Random Effects	RE	FE			RE	FE		
School-by-year Fixed/Random Effects			RE	FE			RE	FE

Table A-5: Comparison of Probit to Other Specifications (Exit Washington Public Schools)

	Odds Ratios				Marginal Effects			
Program Name	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Antioch Univ.	0.682	0.680	0.718	0.746	-0.033	-0.031	-0.028	-0.024
Central Washington Univ.	0.515	0.533	0.518	0.532	-0.041	-0.045	-0.041	-0.043
City Univ.	0.606	0.620	0.624	0.639	-0.032	-0.034	-0.030	-0.032
Eastern Washington Univ.	0.481	0.502	0.515	0.530	-0.041	-0.046	-0.036	-0.040
Evergreen State College	0.734	0.729	0.724	0.752	-0.022	-0.026	-0.023	-0.025
Gonzaga Univ.	0.809	0.813	0.823	0.849	-0.016	-0.018	-0.014	-0.016
Heritage Univ.	0.414	0.419	0.432	0.463	-0.046	-0.053	-0.044	-0.049
Northwest Univ.	0.935	0.929	0.887	0.879	-0.006	-0.003	-0.012	-0.006
Pacific Lutheran Univ.	0.729	0.739	0.726	0.745	-0.022	-0.025	-0.023	-0.024
St. Martin's Univ.	0.526	0.548	0.552	0.566	-0.039	-0.042	-0.036	-0.038
Seattle Pacific Univ.	0.717	0.720	0.748	0.757	-0.026	-0.026	-0.023	-0.022
Seattle Univ.s	0.816	0.822	0.851	0.868	-0.017	-0.017	-0.014	-0.012
Univ. of Puget Sound	0.821	0.828	0.853	0.871	-0.013	-0.016	-0.010	-0.013
UW - Bothell	0.527	0.536	0.523	0.506	-0.050	-0.046	-0.051	-0.046
UW - Seattle	0.705	0.712	0.721	0.730	-0.025	-0.027	-0.024	-0.025
UW - Tacoma	0.645	0.659	0.673	0.719	-0.034	-0.034	-0.030	-0.030
Walla Walla Univ.	0.593	0.604	0.555	0.537	-0.032	-0.038	-0.038	-0.041
Washington State Univ.	0.603	0.616	0.620	0.633	-0.032	-0.036	-0.031	-0.033
Western Washington Univ.	0.551	0.564	0.579	0.591	-0.040	-0.042	-0.036	-0.038
Whitworth Univ.	0.786	0.809	0.827	0.838	-0.015	-0.020	-0.012	-0.017
Specification	Probit	Logit	Probit	Logit	Probit	OLS	Probit	OLS
School Fixed/Random Effects	RE	FE			RE	FE		
School-by-year Fixed/Random Effects			RE	FE			RE	FE