The Impact of School Voucher Systems on Teacher Quality in Public and Private Schools: The Case of Chile

Jere R. Behrman, Michela Tincani, Petra E. Todd, Kenneth I. Wolpin [1]

August, 2013

[1]Jere R. Behrman is W.R. Kenan Jr. Professor of Economics and Sociology and a PSC Research Associate at the University of Pennsylvania. Michela Tincani is a post-doctoral research fellow at University College London. Petra E. Todd is Alfred L. Cass Term Professor of Economics, a PSC Research Associate at the University of Pennsylvania and an Associate of the NBER and IZA. Kenneth I. Wolpin is Walter H. and Leonore C. Annenberg Professor in the Social Sciences and a PSC Research Associate. We are very thankful for support from the Spencer Foundation.

Abstract

Chile is unusual in having long-term experience with nationwide school vouchers and a large private school sector that serves more than half of all students. A key criticism of school voucher systems is that they make it easier for private schools to attract the better teachers to the detriment of the public school system. This paper uses data from Chile to develop and estimate a discrete choice dynamic programming (DCDP) model of teacher and non-teacher labor supply decisions and to explore how wage policies affect the composition of the teacher labor force in both public and private schools. In the model, individuals first decide whether to get a teaching degree and then choose annually from among five work/home sector alternatives. Estimation is based on longitudinal data from the 2005 and 2009 waves of the *Encuesta Longitudinal Docente (ELD)* teacher survey, combined with longitudinal data from the 2002, 2004, 2006 and 2009 waves of the *Encuesta de Protección Social (EPS)*. Empirical results show support for the concern that private voucher schools attract better teachers than municipal schools, largely because they pay higher productivity teachers more. However, the existence of the private voucher sector also draws higher productivity individuals into teaching and improves the overall pool of teachers.

1 Introduction

In 1981, Chile adopted an innovative nationwide school voucher system for primary and secondary education that still operates today.[1] The voucher reform dramatically changed the educational landscape, greatly increasing the demand for and the supply of private schools. Attendance at private schools more than doubled, with private schools today accounting for more than half of total school enrollment. Although there has been much speculation and debate about likely effects of school voucher programs (e.g. Neal, 2002, Hoxby 2002, 2003a,2003b, Ferreyra 2002), most of the evidence from U.S. data comes from studies examining short-term effects of relatively small-scale privately-funded voucher programs (e.g., Rouse 1998, Krueger and Zhu 2003, Yau 2004). Chile is unique in having long-term experience with a large-scale school voucher system.

School vouchers in Chile are publicly funded with voucher funds following the child to private schools that agree to accept the voucher as payment of tuition. Both governmental and private schooling sectors coexist with free entry into the private sector and some governmental monitoring of the quality of all schools.[2] There are three broad types of schools: municipal schools, private subsidized schools, and private non-subsidized (fee-paying) schools. Until 1993, private subsidized schools and municipal schools were financed primarily through per capita governmental vouchers, but in 1993 there was a change in the rules to allow public and private schools to impose a small tuition charge on top of the voucher.[3] Private non-subsidized schools, which include both religious (mainly Catholic) and lay schools, are financed from private tuition.[4] Parents are free to choose among municipal and both types of private schools.[5]

Advocates of school voucher systems cite their value in fostering competition in both public

[1]The voucher reform was one of several privatization and decentralization efforts introduced by Augusto Pinochet's military government.

[2]For example, all schools are required to have licensed teachers. Schools also do not receive additional voucher payments for class sizes that exceed 45 students. See Verhoogan and Urquiola, 2009.

[3]Municipal schools sometimes also receive some additional funding in the form of governmental transfers when the voucher amounts are not sufficient to cover the school's operating expenses.

[4]Private subsidized schools can be for profit or not for profit; private nonsubsidized schools are usually for profit. About three quarters of private voucher schools are for-profit schools. (Elacqua, 2006).

[5]In all types of schools, students are required to take standardized tests, called the SIMCE tests. Each year one or two grades are chosen for these tests among the 4th, 8th and 10th grade. The school's average test results are published annually and parents can compare the performance of locally available schools.

and private schools and improving school quality (Rouse 1998, Hoxby 2003a, 2003b). Critics caution that they deplete public schools of revenue and of their best teachers (Ladd 2002). Most studies of Chile's school voucher program (e.g. McEwan and Carnoy 2001, Sapelli and Vial, 2002, Contreras, 2002, Tokman 2002, Hsieh and Urquiola 2003, McEwan, 2001, Tincani, 2013, Bravo, Contreras and Sanhueza, 1999) compare test scores of children in different kinds of public and private schools. The evidence on whether public or private schools are relatively more effective in producing higher math and reading scores is mixed.[6]

It is widely perceived that Chile's 1980 voucher reform led to significant changes in the allocation of teachers across different types of schools, in part because it was accompanied by decentralization measures that transferred the control of public schools to municipal authorities.[7] Many public school teachers were laid off and had to reapply for their jobs, now in the municipal sector, or to find jobs in the private sector. In addition, teacher union contracts were revoked, giving public schools greater flexibility in hiring and firing teachers, and national curriculum standards were relaxed, giving schools more leeway in setting their own curriculum.[8] After the restoration of the democractic government in 1990, the teacher's association was reinstated and teacher pay was increased, nearly doubling. Today, teachers in Chile's public school system again belong to a powerful national teachers' union. Private school teachers are usually members of a smaller, school-level teachers' association, although sometimes they can also be members of the public teachers' association.

One of the key concerns about school voucher systems is that they put private schools in a better position to attract the best teachers to the detriment of public schools. Many education researchers suggest that public school salary schedules create inefficiencies in the teacher labor market, because salaries are often based on rigid formulae that depend on experience and educational background and because salaries do not respond flexibly to teacher shortages or to reward better teachers. For example, Hoxby (2002) shows that salary schedules in charter and private schools

[6]Estimation is made difficult by multiple selection problems, namely, that types of children attending each school are self-selected and because unobserved factors that determine student performance are likely to be related to the choice of school.

[7]Prior to these reforms, Chile had a long tradition of providing some public support for private (mainly Catholic) schools, but the introduction of the voucher system greatly increased the level of support going to private schools.

[8]Carnoy (1997).

in the United States exhibit less wage compression than in public schools and are more strongly correlated with teachers' backgrounds in math and science, two fields in which there are commonly shortages, and with teachers' SAT scores. If private schools are better able to tailor compensation to teaching ability, then, unless there are other compensating factors, one would expect better teachers to select into the private teaching sector where they receive higher wages.

This paper uses data from Chile to study teacher and non-teacher labor supply decisions in a dynamic context. We examine how teacher compensation schedules in the municipal and private teaching sectors affect the decision to become a teacher, the decisions about in what type of school to teach, and the decision about whether to accept a non-teaching job or be out of the labor force. We also investigate the empirical support for whether private voucher schools attract higher quality teachers than municipal schools on average. In particular, we explore differences in the kinds of teachers that choose to teach in the public and private sectors and the extent to which differences in teacher compensation across public and private sectors explain the selection patterns.

The dynamic decision-making model we develop extends earlier models of Steinbrickner (2001a,2001b) to allow for three teaching sectors (public, private voucher, private nonvoucher), a non-teaching sector and a home sector, and to incorporate the initial choice about whether to become a certified teacher, which is important to capture labor supply responses of new college graduates.[9] In the model, individuals first decide whether to obtain teaching certification, and then, individuals who are certified receive wage offers and decide among five work/home sector alternatives (i) work in a municipal school, (ii) work in a private subsidized (voucher) school, (iii) work in a private nonsubdizied school, (iv) work in a non-teaching job, or (v) not work. Individuals who are not certified can only choose (iv) or (v). Labor market experience in teaching and non-teaching accumulates endogenously.

Because fertility is also potentially an important factor related to women's decisions to work and to enter into the teaching profession, the model incorporates fertility as a stochastic process that depends on state variables. The utility from choosing a particular sector in each time period depends both on pecuniary factors (wages) and nonpecuniary factors (e.g. the number of children, nonpecuniary perceived benefits). Our model also allows for unobserved heterogeneity in wages and

[9]In Chile, teacher certification is required to work in any type of school.

preferences using the Keane-Wolpin (1997) multinomial types approach.[10]

Our analysis samples are drawn from two longitudinal surveys in Chile. One is a survey called the *Encuesta de Protección Social* (EPS), which gathered information from a random sample of working-age Chileans.[11] We use data collected in the 2002, 2004, 2006 and 2009 waves. Most relevant for our analysis is the information on demographics, work and lay-off history, fertility, wages, and educational attainment. We use in estimation only individuals who graduated from college or obtained their teaching certification after 1990. Of the 816 such individuals in the EPS sample, 12.1 percent received a teaching certificate. Given the small sample size of "teachers" in the EPS survey, we use the longitudinal information only for the 690 "non-teachers" in estimating the model.

To obtain longitudinal information on teachers, we use the ELD (*Encuesta Longitudinal Docente*), which was collected for the first time in 2005 and then again in 2009 for the purpose of studying the wages and working conditions of teachers and school administrators. The survey was administered to about 6000 current and former primary and secondary school teachers (as well as a sample of administrators). The data allow study of the labor market outcomes and career trajectories of teachers and how they are affected by the school voucher system and other changes affecting their wages or working conditions. They contain rich retrospective information on education and training, labor force history (total teaching and other experience) as well as five years detailed information on the type of schools in which the teachers/administrators worked. The data also include demographic information (age, gender, fertility, marital status, family background), starting wage, current wage, hours worked, type of labor market contract, and information on occupational conditions. Our analysis is restricted to individuals in the ELD data who obtained their teaching certification after 1990.[12] There are 1,401 such individuals, for whom there are 8,147 observations.

The discrete choice dynamic programming (DCDP) model is solved using standard methods (see Keane, Todd, and Wolpin, 2010) and the parameters are estimated by simulated method of

[10]The approach is similar to Heckman and Singer's (1984) use of discrete types to control in duration analysis.

[11]The first round of data were collected under the survey name *Historia Laboral y Seguridad Social* (HLLS). These data were collected by the Microdata Center at the University of Chile, under the leadership of David Bravo.

[12]As noted, the teacher's union was reinstated in 1991, which led to restructuring of teacher wages. For this reason, we only use in estimation teachers who have been working under the new system. See further discussion below.

moments. This estimation procedure permits combining moments from our different data sources (the EPS and the ELD datasets).[13] After estimating the model, we use it to examine how teacher labor supply, both overall and in the public and private teaching sectors, responds to compensation policies. Results show that the teaching sector is composed on the whole of relatively higher productivity individuals, as captured by the unobserved types in the model, in comparison to the non-teaching sector. Within teaching, the private schooling sectors (both subsidized and unsubsidized) attract higher productivity individuals than does the municipal sector. Simulations based on the estimated model show that increasing the municipal sector wage by 20% would increase the number of certified teachers, but would not increase the "quality" of teachers employed, as the higher wage also would attract lower productivity types into the teaching profession.[14]

An important distinction between municipal wage offers and private schooling sector wage offers is that the municipal sector has a rigid schedule in which everyone is paid according to their teaching experience and not according to other productivity attributes (e.g. teaching ability). Our simulations show that setting the municipal wage schedule equal to the wage offer function used in the private voucher sector, which distinguishes among productivity types, would generate increases in teacher quality within the municipal sector, at the expense of lower teacher quality in the private voucher sector. We also simulate the effect of eliminating the private voucher sector as an employment option, which would increase the quality of teachers who then choose to teach in the municipal schools, but would lower the overall average quality of teachers in all sectors. Thus, the existence of the voucher schooling sector increases the average quality level of all teachers.

The paper proceeds as follows. The next section (section two) describes the related literature on teacher labor markets. Section three describes the model and section four the estimation approach. Section five discusses the data sources and sample restrictions and section six presents the parameter estimates and results based on simulations of the model.

[13]Our estimation approach incorporates weights needed to adjust for oversampling of teachers in unsubsidized schools in the ELD and for stratified sampling in the EPS.

[14]Manski (1987) reports a similar finding for a static occupational choice model estimated on U.S. data

2 Related literature

There is an extensive literature that analyzes the determinants of entry into and exit from the teaching profession in the United States and in Europe. A smaller subset of the literature is concerned with teacher quality and whether and to what extent wage policies can affect teacher quality. We summarize the literature below, grouping the studies into whether they focus on teacher entry, teacher retention, or teacher quality.

2.1 Teacher entry

An early study by Manski (1987) used the National Longitudinal Survey of the High School Class of 1972 (NLS-72) to estimate probit models for the teacher/non-teacher occupational choice decision. Manski finds that a general pay increase does not improve teacher quality, because it attracts both low- and high-quality teachers to the profession. However, he finds that a 10% increase in teaching salaries, coupled with a minimum SAT score requirement, would maintain the supply of teachers and, at the same time, raise their average academic ability compared to all college graduates. A more recent study by Shin and Moon (2006), using the National Longitudinal Survey of Young Women, estimates that higher relative salaries are effective in inducing female college graduates to enter into teaching.[15] Bacolod (2007), using the National Center for Education Statistics Baccalaureate and Beyond Longitudinal Study, estimates nested logit models for the decision to enter into the teaching profession and the decision of whether to teach in urban, suburban, or rural schools. She finds that salaries are important in the occupational entry decision and that working conditions are important in determining where new graduates choose to teach.

Using the British 1980 Graduate Cohort data, Dolton (1990) finds that relative starting earnings in teaching and earnings growth are positively related to the probability of becoming a teacher and to teacher retention. Dolton and Mavromaras (1994) investigate how British graduates' occupational choices changed between 1970 and 1980, with reference to the choice of becoming a teacher. They find that the salary responsiveness of females is less than that of males, and that the

[15] His estimates control for choice of college majors, but they do not investigate what determines the choice of college major.

responsiveness declines over time for both females and males.[16] Wolter and Denzler (2004), using surveys of graduates of Swiss universities for 1981-2001, estimate selection models for salaries for teachers and non-teachers and finds positive self-selection of teachers into teaching. Using data for the Norwegian teacher labor market, Falch (2010) estimates the elasticity of teacher labor supply to be about 1.4, with a range 1.0-1.9, depending on the model specification. Hernani-Limarino (2005) examines how well teachers are paid relative to comparable non-teachers in 17 Latin American countries. He finds that relative salaries for teachers vary widely across Latin America, with teachers in some countries (Argentina, Chile, Colombia, El Salvador, Honduras, Panama, Paraguay, and Peru) paid more on average than other workers with comparable education, teachers in Nicaragua paid less on average, and teachers in Bolivia, Brazil, Costa Rica, the Dominican Republic, Ecuador, Mexico, Uruguay, and Venezuela paid roughly the same.

Mizala and Romaguera (2005) describe changes over time in the teacher salary structure in Chile. In the 1980s, teachers experienced a 32 percent decline in real salaries due to governmental budgetary reductions and the number of students entering education programs dropped 43 percent. As previously noted, the teachers' union was reinstated in the early 1990s. Between 1990 and 2002, real teachers' salaries increased 156 percent. There was a 39 percent increase in the number of education students, and the average score on the college entry examination for applicants to education programs increased 16 percent.

2.2 Teacher retention

Many teachers exit teaching after fairly short employment durations. There have been a number of studies examining the decision to exit from teaching in the United States. Many have used state-level data on teachers working in particular localities, including Georgia–Scafidi et al. (2006); Michigan–Murnane and Olsen (1989); Missouri–Podgursky et al. (2004); New York–Rees (1991), Mont and Rees (1996), Brewer (1996), Ondrich et al. (2008); North Carolina–Murnane and Olsen (1990), Clotfelter et al. (2008), Guarino et al. (2011); Pennsylvania–Greenbaum (2002); South Carolina–Richards and Sheu (1992); Texas–Hanushek et al. (1999); Washington–Theobald (1990),

[16]The paper also presents a counterfactual prediction of the decisions that each cohort would have made had they experienced the market conditions of the other and estimates a decomposition of the changes in the average probabilities of becoming a teacher due to remunerative and other factors.

Theobald and Gritz (1996); and Wisconsin– Imazeki (2005). The results indicate that salaries paid to teachers are negatively related to their propensities to exit teaching and positively related to durations in first teaching positions. A common finding is that salary effects are larger for men than for women. Finally the estimates generally indicate that teachers with higher qualifications (as measured by test scores and degree subject) and those who live in areas with higher average nonteaching salaries are more likely to leave teaching.[17]

A limitation of most of administrative state-level datasets is that they do not follow teachers that move out of state. Stinebrickner (1998) and Stinebrickner (2001a,2001b) use individual level survey data from the NLS-72, in which teachers who move are followed. Stinebrickner (1998) analyzes data for people certified as teachers in 1975-1985; the duration of the first teaching spell was four years or less for half of these individuals. He estimates a proportional hazards model for the decision to exit teaching that includes observable demographic and school characteristics as well as school- and individual-level unobservable heterogeneity. He finds that the lengths of teachers' first spells in teaching are more responsive to salaries than to improved working conditions, such as smaller student-teacher ratios. He also finds marriage and fertility to be important determinants of exiting the teaching profession.

Stinebrickner (2001a) uses a DCDP framework similar to the one we use to model the relationship between personal characteristics, salaries, and the decision process of certified teachers. In each school year, the model allows teachers to choose among teaching, nonteaching, and leisure options. The estimated model is used to simulate two counterfactual policies: a uniform teacher salary increase of 25% and an increase on average of 25%, but with the amount of the raise increasing with the Scholastic Aptitude Test (SAT) score of the teacher (as a proxy for ability or quality). His simulations show that salary increases are more likely to reduce the amount of time spent in nonteaching employment than they are to reduce time spent out of the labor force altogether. The wage effect on the decision to continue working as a teacher is greater for men than for women. Both policies raise the fraction of years spent in teaching by approximately the same amount (0.48

[17] For example, Ingersoll (2003), based on the United States Schools and Staffing Survey and Teacher Follow-up Survey data on public school teachers from 1987-2000, reports that 40-50% of beginning teachers leave by the end of their fifth year with higher exits in high-poverty and urban schools and with reported reasons for exiting including job dissatisfaction due to low salaries, lack of support, discipline or pursuit of better jobs/careers.

to 0.72), but they differ in the extent to which they attract high quality teachers, as measured by SAT scores. [18]

Dolton and van der Klaauw (1995, 1999) analyze decisions to leave the teaching profession within a competing risks framework.[19] The data analyzed are a sample of individuals who graduated from UK universities in 1980 over years 1980-1987. Their results indicate the importance of teacher salaries and opportunity wages as determinants of teacher turnover.

Finally, the Falch (2011) study described above also examines the effect of salaries on teacher leaving decisions using a natural experiment approach. Teachers in schools with a lot of prior teacher vacancies received a salary premium of about 10 percent during 1993-94 to 2002-03. Using a school fixed effects model, he finds that the salary premium reduces the probability of voluntary quits by six percentage points, which implies a short-run labor supply elasticity of about 1.25.

2.3 Teacher Quality

Ballou and Podgursky (1995) use estimates of entry and exit behavior from other studies to simulate the impact of changing teacher salaries on teacher quality. They conclude that a 20% increase in salaries would have little impact on teacher quality, because higher salaries reduce exits, which lowers the number of teaching vacancies and reduces incentives to invest in teacher training, particularly for higher ability individuals with good opportunities elsewhere. They argue that to raise teacher quality, salary increases should be targeted towards those with higher abilities. Ballou and Podgursky (1997) use data from the Schools and Staffing Surveys (SASS) of 1987-8 and 1990-1, the Surveys of Recent College Graduates (SRCG), and SAT scores to examine patterns in teacher pay and teacher quality (as indicated by SAT scores) in the 1980s among more than 8,000 public schools. They find no significant relationship between state-level changes in teacher salaries and changes in SAT scores or the share of high schools students intending to major in education between 1979 and 1989.

Figlio (2002) uses panel data on new teachers from the SASS supplemented with Common

[18]Stinebrickner (2001b) presents a parallel study using a DCDP framework with a more flexible structure for unobserved heterogeneity but with similar results with regard to teacher supply responsiveness to salary increases.

[19]The econometric model allows for a flexible, semiparametric specification of the duration dependence structure and of the unobserved heterogeneity distribution in the exit-specific hazard functions.

Core Data (CCD) and data from the Census of Governments for newly-hired teachers in public school districts that changed their salaries between 1987-8 and 1993-4 to investigate whether school districts can improve the quality of the teachers they hire (as indicated by their having graduated from selective colleges and majored in the subject matter they teach) by unilaterally increasing teacher salaries. For nonunion school districts, he finds a significant positive relation between teacher salaries and that district's probability of hiring well-qualified teachers. This relationship, however, is not found in unionized school districts.

Chen (2009) examines the phenomenon of over-supply of teachers but shortage of qualified teachers in Indonesia. Using a sample of college educated workers from the 2001-2008 Indonesian Labor Force Surveys and a structural model, he estimates the effect of a proposed teacher law, which could give a significant pay increase (i.e., a 100 percent teacher salary increase for certified teachers with a minimum four-year college education or above). He finds that the relative salary of teachers and of alternative occupations significantly influence teacher entry decision. He also finds that the wage rate set by the teacher law would increase the share of teachers approximately from 16 to 30 percent of the college-educated labor force.

Using data from Chile, Tincani (2013) evaluates the costs and impact of teacher labor market policies on student outcomes. She estimates an equilibrium model of entry into teaching, sorting of teachers across schools, parental school choice and private schools' wage and tuition setting. She uses the estimated model to simulate different pay and recruitment schemes. She finds that, compared to across the board wage increases, wage changes tied to teachers' skill levels are more cost-effective at increasing mean student achievement and decreasing the achievement gap by income. Unlike Tincani (2013), this paper does not examine the equilibrium policy response of parents' and private schools' optimal behavior, and it does not quantify impacts in terms of student outcomes. However, the model in this paper is dynamic, capturing the forward-looking nature of career decisions, whereas Tincani (2013) uses a static model.

3 Model

This section describes the model that we develop and estimate to analyze the initial decision to become certified to teach and subsequent decisions about whether to work, whether to teach and, if teaching, whether to teach in a public, private subsidized or private unsubsidized school. The DCDP framework that we adopt incorporates forward-looking behavior in which individuals face uncertainty about their future preferences, wage offers, fertility and likelihood of a layoff. Model parameters are estimated using information on demographic characteristics (gender, age at certification, fertility), teacher certification, work sector choices, wages and layoffs. The estimation sample is restricted to college graduates who graduated after 1990.[20]

Individuals are assumed to make choices that maximize in each period their expected discounted value of remaining lifetime utility. In the first model period, individuals decide whether to become certified to teach or to graduate without certification. Thereafter, individuals receive annual wage offers. Those who have been certified to teach receive wage offers from schools in the municipal sector (M), in the private subsidized/voucher sector (V), and in the private unsubsidized sector (U). They also receive non-teaching wage offers (NT). Those who are not certified to teach only receive offers from the non-teaching sector. Both certified and non-certified individuals can also opt to not work and remain at home (H). After receiving the offers from the different sectors, individuals who are certified decide whether to stay home, work in one of the three types of schools, or work in the non-teaching sector. As described below, individuals also face the possibility of being laid off. The career decision model ends at retirement, assumed to be age 65 for men and 60 for women, the ages at which retirees could obtain pensions during the time period considered.

The initial conditions of the model are gender, the age at which individuals are certified to teach, $a_i^G \in \{22, 23, ..., 40\}$, for those certified, or else the age of college graduation, and number of children at the time of certification. The model allows for different unobserved "types" of individuals, denoted by k. Types are allowed to differ in skill endowments that may affect wage offers, in fertility preferences and in the nonpecuniary value attached to each alternative, as described below.

3.1 Decision to become certified to teach

In the initial period, at the age of graduation/certification a_i^G, individual i decides whether to become certified to teach (either by earning an undergraduate or post-graduate degree in education).[21] The

[20] Teaching in Chile requires a college degree. Additional sample restrictions are described in detail below.

[21] There are four ways one can become certified to teach in Chile: *i.* degree in education (6-11 semesters), *ii.* degree in another area (10-12 semesters) + postgraduate degree in education (2-4 semesters), *iii.* teaching experience

flow utilities associated with the education option (E) and the non-teaching option (NE) are:

$$\begin{aligned} U^E_{ia^G} &= \sum_k \lambda^E_{0k} I(type_i = k) + \lambda^E_1 D^f_i + \lambda^E_2 a^G_i + \eta^E_i \\ U^{NE}_{ia^G} &= 0, \end{aligned}$$

where $I(type = k)$ is an indicator equal to one if the individual is of type k and D^f_i is an indicator variable that equals 1 if female.[22] It is assumed that the preference shock follows a normal distribution, $\eta^E_i \sim N(0, \sigma^2_\eta) \quad \forall i$.

3.2 Sector decisions

Individuals who earn an education degree then choose in each subsequent period (until retirement) among five mutually exclusive and exhaustive alternatives: whether to teach in a public municipal (M), private subsidized (V) or private unsubsidized (U) school, to work in the non-teaching (NT) sector or to stay home (H). We denote $d^{(1)}_{ia} = 1$ if M is chosen by individual i at age a (and zero otherwise), $d^{(2)}_{ia} = 1$ if V is chosen (and zero otherwise), $d^{(3)}_{ia} = 1$ if U is chosen (and zero otherwise), $d^{(4)}_{ia} = 1$ if NT is chosen (and zero otherwise) and $d^{(5)}_{ia} = 1$ if H is chosen (and zero otherwise).

Period-specific utilities associated with working depend on wages as well as on nonpecuniary factors.[23] The wage offer schedule in the municipal sector depends only on total teaching experience, reflecting the fact that wages are calculated using a rigid formula according to guidelines set by negotiations between the teachers' union and the government. The wage offer schedule is given by

$$ln(w^M_{ia}) = \alpha^M_0 + \alpha^M_1 tx_{ia} + \alpha^M_2 tx^2_{ia} + \epsilon^M_{ia}$$

where w^M_{ia} is the wage offer to individual i of age a and tx_{ia} is individual $i's$ total teaching experience (across all teaching sectors). The wage offer does not depend on demographics, such as

+ short university degree (2-5 semesters), *iv.* teaching experience + government authorization. According to the teacher census (*Idoneidad Docentes*), 90% of all teachers get certified through channel one, 5% through channel two and 5% through channels three and four. In the model we do not distinguish between channels one and two and we do not allow for channels three and four.

[22] The utility for the non-education option is normalized to zero because only the difference in utilities can be identified.

[23] Utility is assumed to be linear in consumption and additively separable in the non-pecuniary aspects of employment and home. There is thus no motive for saving or borrowing and consumption is set equal to wages without loss of generality.

gender, because the wage schedules for men and women in the municipal sector are the same. The unobserved component of the wage offer, ϵ_{ia}^{M}, reflects some adjustments to wages that depend on factors such as working conditions and managerial responsibilities.

Wage offers in the other education sectors (V and U) and in the non-education sector (NT) are assumed to be based on individual skills. An individual's skill level in the teaching sectors depends on total teaching experience (as in the municipal sector), gender, unobserved type and an idiosyncratic shock, ϵ_{ia}^{j}, $j = V, U$. An individual's skill level in the non-teaching sector depends on non-teaching experience, ntx_{ia}, total teaching experience, whether the individual has an education degree, D_i^e, gender, unobserved type and an idiosyncratic shock, ϵ_{ia}^{NT}. Wage offers in these sectors are given by

$$\begin{aligned}
ln(w_{ia}^{V}) &= \sum_k I(type_i = k)\alpha_{0k}^{V} + \alpha_1^V tx_{ia} + \alpha_2^V tx_{ia}^2 + \alpha_3^V D_i^f + \epsilon_{ia}^{V} \\
ln(w_{ia}^{U}) &= \sum_k I(type_i = k)\alpha_{0k}^{U} + \alpha_1^U tx_{ia} + \alpha_2^V tx_{ia}^2 + \alpha_3^U D_i^f + \epsilon_{ia}^{U} \\
ln(w_{ia}^{NT}) &= \sum_k I(type_i = k)\alpha_{0k}^{NT} + \alpha_1^{NT} tx_{ia} + \alpha_2^{NT} ntx_{ia} + \alpha_3^{NT} ntx_{ia}^2 + \alpha_4^{NT} D_i^e + \alpha_5^{NT} D_i^f + \epsilon_{ia}^{NT}
\end{aligned}$$

It is assumed that all (log) wage shocks are normally distributed and independent; any correlation in wage offers across sectors comes through the unobserved types.

Period-specific utilities also depend on nonpecuniary aspects of sector-specific jobs. Individuals are assumed to vary in their valuations according to their type. In addition, individuals incur search costs associated with switching work sectors, c^s, being laid off, c^l, and returning to work after a period of absence, c^w. The per-period utilities at ages $a > a_G$ associated with each work option $j = M, V, U, NT$ for an individual i of unobserved permanent type $k \in 1, 2, ..K$ are:

$$\begin{aligned}
U_{ia}^{M} &= w_{ia}^{M} + \sum_k \beta_{0k}^{M} I(type_i = k) + c^s I_{C_s} + c^w I[d_{i,a-1}^{(5)} = 1] + c^l I[D_{i,a}^{l} = 1], \\
U_{ia}^{V} &= w_{ia}^{V} + \sum_k \beta_{0k}^{V} I(type_i = k) + c^s I_{C_s} + c^w I[d_{i,a-1}^{(5)} = 1] + c^l I[D_{i,a}^{l} = 1], \\
U_{ia}^{U} &= w_{ia}^{U} + \sum_k \beta_{0k}^{U} I(type_i = k) + c^s I_{C_s} + c^w I[d_{i,a-1}^{(5)} = 1] + c^l I[D_{i,a}^{l} = 1], \\
U_{ia}^{NT} &= w_{ia}^{NT} + c^s I_{C_s} + c^w I[d_{i,a-1}^{(5)} = 1] + c^l I[D_{i,a}^{l} = 1,]
\end{aligned}$$

where $I_{C_s} = I[d_{i,a-1} \neq d_{ia}, d_{i,a-1}^{(5)} \neq 1, D_{i,a-1}^{l} = 0]$ is an indicator for whether the choice represents a switch in sectors, $D_{i,a}^{l}$ equals one if the individual was laid off (and zero otherwise) and β_{0k}^{j}

represents the nonpecuniary value of alternative $j = M, V, U$ for type k. As seen, an individual who is laid off receives job offers in the same period as the layoff occurs. Lastly, the utility associated with staying at home (not working) is:

$$U_{ia}^{H} = \sum_{k} \beta_{0k}^{H} + \beta_{1}^{H} nk_{ia} I(a_i \leq 50) + \beta_{2}^{H} nk_{ia} D_{i}^{f} I(a_i \leq 50) + \eta_{ia}^{H},$$

where nk is the number of children. It is assumed that $\eta_{ia}^{H} \sim N(0, \sigma_H) \quad \forall i, a$. The utility from staying home depends on the number of children, with the dependence gender specific, restricted to individuals aged 50 or less for whom the children would still be of younger ages. The nonpecuniary value associated with working in the non-teaching (NT) sector is normalized to zero; only the differences in nonpecuniary values are identified.

Fertility is assumed to follow an exogenous stochastic process. In every time period, until age 45 for women and age 50 for men, there is a positive probability, denoted by p_{ia}^{f} of having a child. [24] That is, $nk_{i,a+1} = nk_{ia} + 1$ with probability p_{ia}^{f}, $nk_{i,a+1} = nk_{ia}$ with probability $1 - p_{ia}^{f}$. The probability of having a child depends on the individual's type, gender, the number of children he/she has thus far (nk_{ia-1}) and whether there was a birth in the previous period ($D_{i,a-1}^{b}$).[25] It is specified as a logit,

$$p_{ia}^{f} = \frac{exp(\sum_k \gamma_{0k}^{f} I(type = k) + \gamma_1^{f} a_i + \gamma_2^{f} a_i^2 + \gamma_3^{f} a_i D_i^{f} + \gamma_4^{f} nk_{ia-1} + \gamma_5^{f} D_{i,a-1}^{b})}{1 + exp(\sum_k \gamma_{0k}^{f} I(type = k) + \gamma_1^{f} a_i + \gamma_2^{f} a_i^2 + \gamma_3^{f} a_i D_i^{f} + \gamma_4^{f} nk_{ia} + \gamma_5^{f} D_{i,a-1}^{b})}.$$

As in the case of fertilty, layoffs are treated as an exogenous stochastic process. For individuals in the teaching sector with 15 or fewer years of teaching experience, there is a positive probability of being laid off. Individuals with more experience are assumed to have tenure and to not face a risk of lay-off or nonrenewal.[26] The probability of dismissal/nonrenewal for a teacher, p_{ia}^{lT}, is given by

$$p_{ia}^{lT} = \frac{exp(\gamma_0^{lT} + \gamma_1^{lT} tx_{ia})}{1 + exp(\gamma_0^{lT} + \gamma_1^{lT} tx_{ia})}.$$

[24]In our sample, only 1.06% of fathers have a child after age 50 and only 0.64% of mothers have a child over age 45.

[25]Births are unlikely to occur in consecutive years.

[26]Very few people with more than 15 years of experience report being laid off. In the sample, 1.25% of all teachers with at least 16 years of teaching experience are fired or do not get their contracts renewed as opposed to 2.85% of less experienced teachers.

For individuals working in the non-teaching sector, we similarly assume that there is a positive probability of being laid off that only affects individuals with 15 or fewer years of work experience. The probability of incurring a layoff, p_{ia}^{lNT}, is given by

$$p_{ia}^{lNT} = \frac{exp(\gamma_0^{lNT} + \gamma_1^{lNT} ntx_{ia})}{1 + exp(\gamma_0^{lNT} + \gamma_1^{lNT} ntx_{ia})}.$$

In estimation, we assume that there are three unobserved types ($K = 3$) and that the type distribution follows a multinomial logit distribution that depends on the state variables, Ω_{ia}.

$$Pr(k_i = \tau | \Omega_{ia}) = \frac{e^{\Omega'_{ia}\tilde{\omega}_\tau}}{\sum_{\tau=1}^{3} e^{\Omega'_{ia}\tilde{\omega}_\tau}}$$

We normalize $\omega_1 = 0$ and rewrite the probability of a type as ,

$$Pr(k_i = \tau | X_{ia}) = \frac{e^{\Omega'_{ia}\omega_\tau}}{1 + \sum_{\tau=2}^{3} e^{\Omega'_{ia}\omega_\tau}}.$$

The state space consists of $\Omega_{ia} = [1 \quad D_i^f \quad tx_{ia} \quad ntx_{ia} \quad nk_{ia} \quad d_{i,a-1} \quad D_{i,a}^l \quad D_i^e \quad a_i^G \quad D_{i,a-1}^b]'$.[27] Specifically, in the above expression,

$$\begin{aligned} \Omega'_{ia}\omega_\tau \quad = \quad & \omega_{\tau 0} + \omega_{\tau 1} D_i^f + \omega_{\tau 2} tx_{ia} + \omega_{\tau 3} ntx_{ia} + \omega_{\tau 4} nk_{ia} + \omega_{\tau 6} d_{i,a-1}^{(4)} + \omega_{\tau 5} D_{i,a}^l + \\ & \omega_{\tau 6} D_i^e + \omega_{\tau 7} a_i^G + \omega_{\tau 8} D_{i,a-1}^b + \omega_{\tau 9} 1(ELD). \end{aligned}$$

The last term in the summation is an indicator for whether the individual is from the ELD sample, which allows the type distribution to differ between the ELD and EPS samples. The inclusion of the ELD dummy corrects for the effect of choice-based sampling on the distribution of the unobservable types.

4 Estimation approach

The model does not have an analytical solution and is therefore solved numerically by backwards recursion. Model parameters are then obtained by the method of simulated moments, choosing the parameters to minimize the weighted average distance between the outcomes simulated under the model and the outcomes observed in the data.

[27] In the initial time period after graduation, teaching experience, non-teaching experience, the indicator for previous period layoff and the indicator for a birth in the previous period (which is not observed in the data) are set to zero.

4.1 Numerical solution of the dynamic programming problem

We denote the nonstochastic elements of the state space by $\Omega(a)$ and the stochastic elements (the wage and preference shocks) by $\tilde{\varepsilon}(a)$. Given values for the model parameters γ, the individual's maximization problem can be written in any period in recursive form. Specifically, the Bellman equation is:

$$V(\Omega(a), \tilde{\varepsilon}(a); \gamma) = \max_{d_{ia}} \{U_{ia} + \delta Emax[V(\Omega(a+1), \tilde{\varepsilon}(a+1); \gamma)|\Omega(a), d_{ia}]\}$$

for a_i such that $a_i < a_R$, where δ is the discount factor and a_R, the age of retirement. In the last decision period, the future Emax is set to 0. Let V_a denote the value function at age a. The full solution of the dynamic programming problem is the set of Emax functions for all ages. The dynamic programming problem is solved using standard backwards recursion methods as described, for example, in Keane, Todd and Wolpin (2010).

4.2 Parameter estimation

We estimate the parameters of the model using a conditional simulated methods of moments approach.[28] The moments correspond to the squared difference between actual outcomes (wages, occupational choices) for different groups of individuals (e.g. men, women of different ages) and one period ahead model-based forecasts of the outcomes, conditional on state variables. Let a_0 and a' denote the minimum age and maximum age observed in the data, A the set of all ages, and N_A the cardinality of the set A. Let Ω_{ia} denote the state space of individual i at age a, where $i = 1, ..., N_I$, $\omega_{ia} \in \Omega_{ia}$ an element of the state space and $Z_{ia} \subset \Omega_{ia}$ a subset of the state space.

Let y_{ia} denote an observed outcome measure, which in our application corresponds to wages or indicators for whether a particular choice was made. Let $\hat{y}_{iask}(\gamma)$ denote the predicted value of y_{ia} given model parameters γ, for simulation number s (where $s = 1, ...S$) and an individual of type k, where $k \in \{1, .., K\}$. The predicted outcome value $\hat{y}_{ia}(\gamma)$ is obtained by integrating over the unobserved type distribution and taking the average over simulation draws. That is,

$$\hat{y}_{ia}(\gamma) = \frac{1}{S} \sum_{s=1}^{S} \sum_{k=1}^{K} \hat{y}_{iask}(\gamma; \Omega_a, type_i = k) Pr(k|\Omega_a)$$

[28] See, e.g., Gourieroux and Monfort, 2002.

where $Pr(k|\Omega_a)$ integrates to one and, as noted, is parametrically estimated by a multinomial logit model. The type proportions depend on the state variables (including the fixed initial conditions in the model, gender and age of teaching certification). If the outcome is discrete (1 or 0), then $\hat{y}_{ia}(\gamma)$ is the predicted fraction making the choice of 1 (e.g. of the probability of choosing to work in a particular sector).

Both the EPS data and the ELD data were collected using nonrandom sampling schemes. The EPS data were collected by a stratified sampling scheme. The ELD data include all individuals who were teachers in 1995 or later and the sampling design oversampled certain types of teachers.[29] Because decisions in our model include the decision to become a teacher and the decision with regard to teacher sector, for our purposes, the ELD sample is a choice-based sample. Weights are included in both the ELD and EPS datasets that reweight the sample back to random sampling proportions, (for the ELD sample, random conditional on being a teacher between 1995-2002). Our estimation procedure combines moments from the different datasets, and we use the weights provided in the two datasets to reweight the observations back to random sampling proportions.[30] The EPS sample is used to get the fraction of teachers certified. Let w_i denote the sampling weight of observation i, which does not vary by age.[31] For the ELD sample, we only use observations on outcomes of individuals beginning with the first year after they become teachers (with the state variables referring to their first year of teaching).

We now consider a moment corresponding to the mean squared difference between actual and simulated outcomes for individuals with a particular subset of conditioning state variables Z_{ia} and of an age in the range $\tilde{A} \in A$. Let $D_{i,Z_{ia},\tilde{A}} = 1$ if $\omega_{ia} \in Z_{ia}$ and $a \in \tilde{A}$, else $= 0$. Let $N = N_A \times N_I$, where N_I is the number of individuals and N_A the number of ages over which they are observed.[32] We can write the ith moment condition as [33]

[29] Private school teachers were oversampled.

[30] Recall that we also correct for sample selection based on unobservables through the inclusion of an ELD indicator variable in the type probability function.

[31] The weights have been normalized to sum to the total numbers of observations in the data (respectively, for the two datasets). For the EPS, we use the weights provided in the 2004 survey. For the ELD, we use the weights provided in the 2005 survey.

[32] For ease of notation, we abstract from possibly having an unbalanced panel.

[33] For wage outcomes, we match the product of the wage and the sector dummy. For example, if y_{ia}^M denotes the wage offer in sector M and D_{ia}^M is equal to one if sector M is chosen, we build a simulated outcome $\hat{y}_{ia}^M \hat{D}_{ia}^M$ for

$$f_N^i(\gamma) = \left[\ \frac{1}{N}\sum_{i=1}^{N}\sum_{a=a_0}^{a'}(y_{ia} - \hat{y}_{ia}(\gamma))D_{i,Z_{ia},\tilde{A}}w_i \ \right].$$

In the limit, as $N_I \to \infty$ and $S \to \infty$, the above expression converges to

$$E(y_{ia} - \hat{y}_{ia}(\gamma)|D_{i,Z_{ia},\tilde{A}} = 1)Pr(D_{i,Z_{ia},\tilde{A}} = 1)$$

Stack all the moment conditions into the $m \times 1$ vector $f_N(\gamma)$. The estimator minimizes the criterion

$$\hat{\gamma} = argmin f_N(\gamma)'W_N(\gamma)f_N(\gamma)$$

where W_N is the $m \times m$ dimensional weighting matrix. Let V_N denote the sample variance of the moment vector. Also, W and V are the probability limits of W_N and V_N. The method of moments estimator is distributed as

$$\sqrt{N}(\hat{\gamma} - \gamma) \sim (N(0, (\Gamma W \Gamma')^{-1}(\Gamma' W V W \Gamma)((\Gamma' W \Gamma')^{-1})').$$

The optimal weighting matrix (the one that leads to the most efficient GMM estimator), sets $W_N = V_N^{-1}$. We do not use the optimal weighting matrix in estimation, however, because it is a large matrix that it is difficult to invert in a numerically precise way. The formula given above, which allows for a non-optimal weighting matrix, does not require inversion of V. Appendix A provides detailed information on how Γ, V, and W are estimated.

5 Data Description and Sample Restrictions

In 2002, the Microdata Center of the Department of Economics of the Universidad de Chile conducted a new household survey called *Historia Laboral y Seguridad Social (HLLS)*. In 2004, 2006,

municipal sector wages. The corresponding moment condition is

$\frac{1}{N}\sum_{i=1}^{N}\sum_{a=a_0}^{a'}(y_{ia}^M D_{ia}^M - \hat{y}_{ia}^M \hat{D}_{ia}^M)D_{i,Z_{ia},\tilde{A}}w_i.$

Because the sector choice is an endogenous outcome, the simulated dummy depends on the parameters and its presence introduces discontinuity in the objective function used in estimation. To guarantee asymptotic normality we assume the sufficient condition for smoothness of the limiting objective function of the MSM presented in Theorem 7.1 in Newey and McFadden (1994). Under this assumption, the results of Theorem 7.1 apply and asymptotic normality is guaranteed. Given the complexity of the model, this assumption is imposed instead of derived from the model primitives.

and 2009, it administered follow-up surveys, changing the name of the survey to the *Encuesta de Protección Social (EPS)*, or Social Protection Survey. The data from the EPS, as previously noted, contain demographic and labor market information on 17,246 individuals age 15 or older, including information on household characteristics, education, training and work history, pension plan participation, savings, as well as more limited information on health, assets, disability status and utilization of medical services. Of particular relevance to our analysis are the questions on labor force and participation in training/education, which include retrospective labor force participation and lay-off information (back to 1981), information on educational attainment and fertility, and information on wages for the survey years. In estimation, we use individuals who graduated from college or graduate school and/or obtained teaching certification in or after 1990. The reason for this restriction is that the government introduced the *Estatuto Docente* in 1991, which dramatically changed teaching in municipal schools. Before its introduction, municipal school teachers were not considered public employees; they were subject to the private labor code, had less job security and the wages were not regulated. The *Estatuo Docente* introduced the wage formulae for public school teachers and also increased the wage level. Because the characteristics of the teaching profession changed so dramatically (at least in municipal schools), we decided to only analyze decisions for the subset of teachers who entered under the new system.

The second longitudinal survey we use is the ELD (*Encuesta Longitudinal Docentes*), collected for the first time in 2005 and 2009 for the purpose of studying the wages and working conditions of teachers and school administrators. The survey was administered to 6000 current and former primary and secondary school teachers.[34] The data contain rich retrospective information on education and training, labor force history (total teaching and other experience) as well as five years detailed information on the type of schools in which the teachers/administrators worked. It also gathered demographic information (age, gender, fertility, marital status, family background), health information, starting wages, current wages, hours worked, type of labor market contract, and information on occupational conditions. Our analysis is restricted to individuals in the ELD data who obtained their teaching certification after 1990 with a certification age below or equal to age 40, of

[34] The sampling frame for the ELD consisted of teachers in 1995 (obtained from the Teacher Census) and of individuals who entered into the teaching profession since 1995. Therefore, the ELD covers individuals who over the last twenty years were at some point teachers.

which there are 1,401 individuals. We have 8,147 person-year observations on these individuals.[35]

6 Empirical Results

6.1 Parameter estimates

Table 1 shows the estimated model parameters.[36] The model was estimated incorporating three unobserved types to capture unobservable heterogeneity. The preference parameters associated with having an education degree relative to a non-education college degree are negative for all three types, indicating that, other things equal, people have a preference for non-education degrees. The coefficient on the female indicator is positive, showing that men dislike education degrees more than women.

The coefficients under the panel labeled “Payoff: Municipal Schools" show the parameters of the wage offer equation (the $\alpha' s$) and the nonpecuniary returns (the $\beta_{0j}^{M\prime} s, j = 1, 2, 3$). Similarly, the panels labeled “Payoff: Voucher Schools," "Payoff: Unsubsidized Schools," and "Payoff: Non-Teaching Sector" show the same parameters for the other sectors. With respect to the wage offer functions, in accordance with union wage schedules, wage offers in municipal schools depend on teaching experience but do not differ by type or gender. On the other hand, voucher and unsubsidized schools, which must compete with municipal schools for teachers, are less constrained by union wage negotiations and are thus are able to discriminate among teachers through the wages they offer. Similarly, wage offers in the non-teaching sector, encompassing a variety of industries and occupations, would be expected to vary by type (and gender).

The estimates in table 1 reveal significant differences in wage offers by type and gender in non-municipal schools and in the non-teaching sector. With respect to gender, for given experience and type, women receive a 10 percent lower wage offer than men in voucher schools, an 8 percent lower wage offer in unsubsidized schools and a 27 percent lower offer in non-teaching jobs. There are also large differences in wage offers among the unobserved types. Type 1's receive the lowest

[35] The model does not allow individuals to work in the non-teaching sector before obtaining a teaching certification. In the ELD sample after applying our sample selection we observe only 7 people with some non-teaching experience at the age of teaching certification. These people have on average 2.29 years of non-teaching experience. In estimation, we set their non-teaching experience at certification to zero.

[36] Because of the relatively short panel, we did not estimate the discount rate, which was set at 0.96.

wage offers in all sectors and type 2's the highest in all sectors. Relative to the municipal schools, for which all types receive the same offers, type 1's are the only group that receives lower offers in all of the other sectors. Experience returns also differ across sectors. For example, the first year of experience adds 5.4% to wages in voucher schools but only 2.5% in municipal schools. After ten years of experience, the voucher school wage will have increased by about 40% but only by about 10 percent in municipal schools. The experience return is largest in the unsubsidized sector, with the first year of experience adding 7.5 percent to the wage offer. The first-year return to (sector-specific) experience in the non-teaching sector is similar to that in the voucher sector, but declines faster with additional years of experience. Interestingly, there is a non-trivial return (2.8 %) to teaching experience in the non-teaching sector, but those with teaching certification receive 17.6% lower wage offers in the non-teaching sector.

Type-specific choices are not only determined by wage offers, but also by the value placed on sector-specific nonpecuniary aspects of employment. Recall that the coefficients in table 1 representing these non-pecuniary returns are relative to the returns in the non-teaching sector. Among the teaching sectors, all of the types value most the non-pecuniary aspects of employment in municipal schools. However, type 1's value the nonpecuniary aspects of employment in the non-teaching sector more than those in the teaching sectors, while both type 2's and 3's value those in the municipal sector more than in the non-teaching sector. Only Type 1's value being at home more than working in any of the sectors. Type 2's place a greater value on working in the municipal sector and in the non-teaching sector than on remaining at home, but a lower value on working in the other sectors and type 3's place a greater value on working in the voucher sector than on remaining at home, but a lower value on working in other sectors. The estimates for the home sector payoff also reveal that children increase the value of remaining at home, but more for women than for men.

With respect to some of the other parameters, the transition (search) costs associated with switching work sectors, switching from the home sector to working and during a layoff are estimated to be substantial in magnitude. The probability of a birth increases with age at a decreasing rate, with births more likely for individuals with more children and less likely if there was a birth in the previous period. The estimated parameters for the dismissal process show that dismissals are a decreasing function of experience, both in the teaching and non-teaching sectors.

6.2 Descriptive statistics and model fit

Tables 2 and 3 present descriptive statistics and evidence on the model fit, based on one step ahead simulations.[37] That is, for each person-year observation, we simulate their wage offers and derive their choices conditional on the observed state variables. In the data, 17.8% of female college graduates in the EPS sample have education degrees in comparison to 6.1% of men. Simulations based on the model come very close to replicating these proportions.

Of the women who are certified to teach, 33.8% are employed in municipal schools, 48.3% in voucher schools, 11.8% in unsubsidized private schools and 2.2% in non-teaching. For college graduates without teaching certification, 75.7% of women are employed in comparison to 85.2% of men. Simulations of the choice distribution based on the model are within 1-3 percentage points of the data.[38] The model fit to accepted wages is also close; the deviations are generally less than 5%.

There is a strong propensity for those with an education degree to remain employed in the same school sector from one year to the next. In particular, 96.8 percent who are employed in a municipal school in one year are employed in a municipal school the next year. The corresponding figure for those in a voucher school is 96.2 percent and for those in an unsubsidized school 93.4 percent. Simulated data are quite close, 95.7, 96.1 and 90.8 percent.[39]

Table 3 provides information about how the types differ and about how types are distributed in the population. The first row of the table shows the fraction of men and women college graduates estimated to be of each type. As seen, 73.0% of females are estimated to be of type 1, 1.8% of type 2 and 25.3% of type 3. The type distribution is similar for men, with 72.1% type 1, 6.0% type 2 and 22.1% type 3. The type distribution is much different for those who chose an education degree. For women, type 3's comprise almost three-fourths of all college graduates with an education degree, while for men, type 2's and type 3's comprise 94 percent of college graduates with an education degree, split almost evenly between the two types. Recalling that table 2 showed that type 1 individuals are the least productive in all sectors in terms of having lower wage offers, our results

[37]The means shown in the table incorporate sampling weights.

[38]The simulations are based on 40 simulation draws.

[39]Although all of these are close quantitatively to the actual data, a chi-square test rejects the hypothesis that they are the same for all but the voucher schools. The chi-square test does not correct the degrees of freedom for estimated parameters in the simulated data.

imply that people who are certified to teach are generally drawn from the higher productivity types among college graduates.

6.3 Policy simulations

Table 4 simulates the effect of a variety of policy interventions that have the potential to attract higher productivity types into teaching and into the municipal sector.[40] These include (a) a bonus to getting an education degree in the amount of two years of municipal wages, (b) a 20% increase in the municipal sector teacher wage offer, (c) the municipal sector adopting the same wage schedule as the voucher sector.[41] We also consider a more radical type of policy that eliminates the voucher school option for teachers to see if the availability of the voucher schools lowers the quality of teachers in the municipal sector.

For each of the policy simulations, we start with the initial conditions for each person and simulate an entire career path for 100 sets of simulation draws.[42] That is, we simulate the decisions individuals make about whether to obtain an education degree and whether and where to work. Table 4 reports the averages across the simulations for what the population would look like in 2004-2007.[43]

The columns under "Baseline" show the type distributions based on the model estimates. As seen, in the baseline, 12.1 of college graduates receive an education degree; 15 percent of them are type 1's, 18.0 percent type 2's and 66.7 percent type 3's. Of those receiving education degrees, almost all (98.6 percent) who work in municipal schools or in unsubsidized schools are type 3, while there is close to an even split of those who work in voucher schools among type 2's (57.2 percent) and type 3's (42.7 percent). In fact, type 2's, the most productive teachers, are found only in the voucher schools.

The first policy simulation evaluates the effect of giving a bonus for obtaining an education

[40] We are abstracting from equlibrium effects and school budget constraints. These effects demonstrate only the supply responses that would be necessary for a full labor market equilibrium analysis.

[41] Chile recently introduced a policy that provides fellowships to individuals who graduate with an education degree.

[42] Our simulated policy effects use the EPS distribution of initial conditions (gender, age at graduation and number of children) rather than the ELD, because the EPS sample is nationally representative and includes both teachers and non-teachers.

[43] These years correspond to those in which the EPS data were collected.

degree in the amount of two years of municipal entry-level wages. As seen in the first row of table 1, the bonus would increase the percentage of women obtaining an education degree from 17.7% to 18.7% and the proportion of men from 6.2% to 6.7%. However, it would also lead to an increase in the percentage of low productivity (type 1) individuals among those earning an education degree, from 18.4% to 19.3% for women and from 6.0% to 6.7% for men, and a reduction in the percentage of the highest productivity type (type 2).

The second policy intervention we consider is a 20% increase in the municipal wage. The simulation shows that the wage increase leads to an increase in the percentages of individuals obtaining an education degree from 12.1% to 13.6% and as with the first policy, to an increases in the share of type 1's among teachers (from 15.3 % to 17.9 %). Moreover, many of the type 1 new entrants choose municipal sector employment, increasing their share from only 1.4 % to 21.5 % of municipal sector teachers.[44] Thus, average teacher quality in the municipal sector falls. This policy also induces type 3's working in the voucher schools to move to the municipal schools, so that type 2's are essentially the only teachers in the voucher schools.

In our next policy simulation, municipal schools are forced to adopt a wage offer function identical to that used in the private voucher schools. Similar in magnitude to the case of the 20 percent increase in the municipal wage, 13.7 percent of college graduates choose an education degree. However, unlike that previous policy, this policy induces the highest productivity types to enter the teaching profession. Specifically, the fraction of those with an education degree who are type 2's increases from the baseline case of 18.0 to 27.3 percent. Moreover, not only are the new entrant type 2's drawn to the municipal sector, but so are those who were working in the voucher schools. Indeed, almost all of the type 2's are now working in the municipal sector, accounting for over one-half (53.0 percent) of municipal sector teachers.

The last policy simulation considers the impact of eliminating the voucher school sector as an employment option for teachers. This change would lower the percentage of college graduates receiving an education degree from 12.1 to 10.4 %, with the fall being especially large for men (from 6.2 to 3.8 %). With the absence of voucher schools, all of the type 2's (all of whom were in voucher schools in the baseline) move to the municipal schools, with type 2's now comprising 11.7 % of the

[44]They also choose to work in the small unsubsidized sector.

municipal school teachers (7.8 % of female teachers and 31.2 % of male teachers). However, the type distribution for those with an education degree would also change, with the share of type 2's dropping by two-thirds (from 18.0 to 6.5 %).

7 Conclusions

Chile's long-term experience with school vouchers on a nationwide scale provides a unique opportunity to learn how a school voucher system affects teacher labor markets. In Chile, the market for private education is competitive and more than half of children attend private schools. Proponents of school voucher systems cite their value in fostering competition and improving the overall quality of public and private schools. Critics often emphasize that voucher systems draw the best teachers out of the public school system and into the private system.

In this paper, we develop and estimated a discrete choice dynamic programming (DCDP) model of occupational choices that we use to evaluate a range of potential policies for improving the quality of teachers. The model builds on earlier related models of Steinbrickner (2001a, 2001b), extending his framework to allow for three teaching sectors (public, private voucher, private non-voucher), as well as a non-teaching and a home sector, and to incorporate the initial choice about whether to become a certified teacher.

The estimated model parameters show that unobservable heterogeneity, incorporated in the model through three discrete types, is an important feature of the data.[45] We found evidence of absolute advantage, namely, that the types are ranked in the same way in terms of productivity across all sectors, with type 1 having the lowest productivity and type 2 the highest.

Simulations based on the estimated model yield a number of interesting findings. First, among college graduates in Chile, people who enter the teaching profession are drawn from the higher productivity types (types 2 and 3). Second, private voucher schools attract higher quality teachers than do municipal schools. Third, if the municipal sector were to adopt the voucher sector wage schedule that tailors pay to type of teacher, the quality of municipal school teachers would increase.

[45] See Keane and Wolpin (1997) for another example of an occupational choice model where unobservable heterogeneity plays an important role.

Fourth, it is difficult to increase quality of teachers in the municipal sector simply by increasing teacher pay there. Increasing municipal teacher wages by 20% does not increase quality because low productivity types are also drawn into that sector. It is possible that increasing pay to induce more entry combined with minimum standards could increase teacher quality, but imposing a minimum standard is outside the scope of our model. Fifth, giving a bonus for getting an education degree induces more people to major in education but does not substantially affect the quality.

Sixth, we performed a simulation that examines how the composition of teachers would change if the private voucher school sector were eliminated as an employment option. We find that not having a private voucher sector would increase the quality of teachers in municipal schools. However, this benefit comes at a cost of lowering the overall quality of teachers because the existence of a private voucher sector, where teacher wages are competitively determined, attracts higher productivity individuals into the teaching profession.

Considering the common criticisms of voucher systems, we find support for the concern that private voucher schools are able to attract better teachers than municipal schools, largely because they pay higher productivity teachers more. But the pool of teachers is not fixed, and the existence of the private voucher sector draws higher productivity individuals into the teaching sector and improves the overall pool of people choosing teaching as a profession.

References

[1] Bacolod, Marigee. (2007): "Who Teaches and Where They Choose to Teach: College Graduates of the 1990s." *Educational Evaluation and Policy Analysis*, 29(3), 155-68.

[2] Ballou, Dale and Michael Podgursky (1995): "Recruiting Smarter Teachers." *Journal of Human Resources*, 30(2), 326-38.

[3] Ballou, D. and M.J. Podgursky (1997): *Teacher Pay and Teacher Quality*. WE Upjohn Inst. Kalamazoo: Michigan.

[4] Bravo, David, Dante Contreras, and Claudia Sanhueza (1999): "Rendimiento escolar, desigualdad y brecha de desempeño privado/público: Chile 1982-1997". Documento de Trabajo N°163, Departamento de Economía, Universidad de Chile.

[5] Brewer, Dominic J. (1996): "Career Paths and Quit Decisions: Evidence from Teaching," *Journal of Labor Economics*, 14:2(April), 313-39.

[6] Carnoy, Martin (1997): "Is Privatization through Education Vouchers Really the Answer? A Comment on West," *The World Bank Research Observer*, Vol. 12, No. 1 (Feb., 1997), pp. 105-116.

[7] Chen, Dandan (2009): "The Economics of Teacher Supply in Indonesia." Washington, DC: World Bank. World Bank Policy Research Working Paper Series, No. 4975.

[8] Clotfelter, Charles, Elizabeth Glennie, Helen Ladd and Jacob Vigdor (2008): "Would Higher Salaries Keep Teachers in High-Poverty Schools? Evidence from a Policy Intervention in North Carolina." *Journal of Public Economics*, 92(5-6), 1352-70.

[9] Contreras, Dante (2002), "Vouchers, School Choice, and Access to Higher Education," Yale University Economic Growth Center Discussion Paper No. 845.

[10] Dolton, Peter J. and Wilbert von der Klaauw (1995):. "Leaving Teaching in the UK: A Duration Analysis." *Economic Journal*, 431-44.

[11] Dolton, Peter J. and Wilbert Van der Klaauw (1999): “The Turnover of Teachers: A Competing Risks Explanation," *Review of Economics and Statistics*, 81(3), 543-52.

[12] Dolton, Peter J. (2006): “Chapter 19 Teacher Supply," E. Hanushek and F. Welch, *Handbook of the Economics of Education*. Elsevier, 1079-161.

[13] Dolton, Peter J. (990): “The Economics of Uk Teacher Supply: The Graduate’s Decision." *Economic Journal*, 100(400), 91-104.

[14] Dolton, Peter J. and Kostas G. Mavromaras (1994): “Intergenerational Occupational Choice Comparisons: The Case of Teachers in the Uk." *Economic Journal*, 104(425), 841-63.

[15] Elaqua, Gregory (2006): “Public, Catholic, and for-profit school enrollment practices in response to vouchers: Evidence from Chile," manuscript.

[16] Falch, Torberg (2010): “The Elasticity of Labor Supply at the Establishment Level." *Journal of Labor Economics*, 28(2), 237-66.

[17] Falch, Toberg (2011): "Teacher Mobility Responses to Wage Changes: Evidence from a Quasi-Natural Experiment." *American Economic Review*, 101(3), 460-65.

[18] Ferreyra, Maria (2007): “Estimating the Effects of Private School Vouchers in Multi-District Economies," *American Economic Review*, Vol. 97, Issue 3, 787-817.

[19] Figlio, David N. (2002): "Can Public Schools Buy Better-Qualified Teachers?" *Industrial and Labor Relations Review*, 55(4), 686-99.

[20] Gourierioux, Christian and Alain Monfort (2002): *Simulation-Based Econometric Methods*, Oxford University Press.

[21] Greenbaum, Robert T. (2002): "A Spatial Study of Teachers’ Salaries in Pennsylvania School Districts." *Journal of Labor Research*, 23(1), 69-86.

[22] Guarino, Cassandra M., Abigail B. Brown and Adam E. Wyse (2011): "Can Districts Keep Good Teachers in the Schools That Need Them Most?" *Economics of Education Review*, 30(5), 962-79.

[23] Hanushek, Eric A., John F. Kain and Steven G. Rivkin (1999): “Do Higher Salaries Buy Better Teachers?," Cambridge, MA: National Bureau of Economic Research. *NBER Working Paper Series*, No. 7082. Available online at: http://www.nber.org/papers/w7082.

[24] Hanushek, Eric A. and Steven G. Rivkin (2006): “Chapter 18 Teacher Quality," E. Hanushek and F. Welch, *Handbook of the Economics of Education*, Elsevier, 1051-78.

[25] Hernani-Limarino, Werner (2005): “Are Teachers Well Paid in Latin America and the Caribbean? Relative Wage and Structure of Returns of Teachers," E. e. Vegas, Incentives to Improve Teaching: Lessons from Latin America. Washington, D.C.: World Bank, 63-102.

[26] Heckman, J. and B. Singer (1984): “A Method for Minimizing the Impact of Distributional Assumptions in Econometric Models for Duration Data," *Econometrica*, Vol. 52, No. 2, pp. 271-320.

[27] Hoxby, Caroline (2002): “Would School Choice Change the Teaching Profession," *Journal of Human Resources*, v. 37, n. 4, 846-91.

[28] Hoxby, Caroline (2003a): “Introduction," in *The Economics of School Choice*, edited by Caroline M. Hoxby, University of Chicago Press: Chicago, p. 1-22.

[29] Hoxby, Caroline (2003b): “Could School Choice be a Tide that Lifts all Boats," *The Economics of School Choice*, edited by Caroline M. Hoxby, University of Chicago Press: Chicago, p. 287.

[30] Hsieh, Chang-Tai and Miguel Urquiola (2003): “When Schools Compete, How Do They Compete? An Assessment of Chile's Nationwide School Voucher Program," *NBER Working Paper No. 10008*, Sept..

[31] Imazeki, J. (2005): “Teacher Salaries and Teacher Attrition." *Economics of Education Review*, 24(4), 431-49.

[32] Ingersoll, Richard M. (2003): “The Teacher Shortage: Myth or Reality?" *Educational Horizons*, 81(3), 146-52.

[33] Keane, Michael P. and Kenneth I. Wolpin (1994): “The Solution and Estimation of Discrete Choice Dynamic Programming Models by Simulation: Monte Carlo Evidence," *Review of Economics and Statistics* (November).

[34] Keane, Michael P. and Kenneth I. Wolpin (1997): "The Career Decisions of Young Men," *Journal of Political Economy*, 105, 3, 473.

[35] Keane, Michael, Petra E. Todd and Kenneth I. Wolpin (2010): "The Structural Estimation of Behavioral Models: Discrete Choice Dynamic Programming Methods and Applications," *Handbook of Labor Economics*, ed. David Card and Orley Ashenfelter, Volume 2, Elsevier, p. 332-461.

[36] Krueger, Alan and Pei Zhu (2004): "Another Look at the New York City School Voucher Experiment," *American Behavioral Scientist*, Vol. 47, Issue 5, 658-698.

[37] Ladd, Helen (2002): “School vouchers: a critical view," *Journal of Economic Perspectives*, 16(4), 3-24

[38] Larranaga, Osvaldo, 2004,Competencia y Participación Privada: la Experiencia Chilena en Educación, Documento de Trabajo # 207, Departamento de Economia, Universidad de Chile.

[39] Lavy, Victor (2007): “Using Performance-Based Pay to Improve the Quality of Teachers." *The Future of Children*, 87-109.

[40] Lavy, Victor (2004): “Performance Pay and Teachers' Effort, Productivity and Grading Ethics." Cambridge, MA: National Bureau of Economic Research. NBER Working Papers, No. 10622. Available online at: http://www.nber.org/papers/w10622.pdf.

[41] Leigh, Andrew (2012): “Teacher Pay and Teacher Aptitude." *Economics of Education Review*, 31(3), 41-53.

[42] Liu, H, Mroz, T. and W. Van der Klaauw (2003): "Maternal Employment, Migration and Child Development," working paper, University of North Carolina, Chapel Hill.

[43] Manski, Charles F. (1987): "Academic Ability, Earnings and Decision to Become a Teacher: Evidence from the National Longitudinal Study of the High School Class of 1972," D. A. Wise, Public Sector Payrolls. Chicago, IL: University of Chicago, 291-316.

[44] McEwan, Patrick J. (2001): "The Effectiveness of Public, Catholic, and Non-Religious Private Schools in Chile's Voucher System," *Education Economics* 9:2, 103-128.

[45] McEwan, Patrick J. and Martin Carnoy (2001): "The effectiveness and efficacy of private schools in Chile's voucher system," *Educational Evaluation and Policy Analysis*, 22(3), 213-239.

[46] Mizala, Alejandra and Pilar Romaguera (2005): "Teachers' Salary Structure and Incentives in Chile," E. e. Vegas, Incentives to Improve Teaching: Lessons from Latin America. Washington, D.C.: World Bank, 103-50.

[47] Mont, D. and D.I. Rees (1996): "The Influence of Classroom Characteristics on High School Teacher Turnover." *Economic Inquiry*, 34(1), 152-67.

[48] Murnane, R.J. and R.J. Olsen (1990): "The Effects of Salaries and Opportunity Costs on Length of Stay in Teaching: Evidence from North Carolina." *Journal of Human Resources*, 106-24.

[49] Murnane, Richard J. and Randall J. Olsen (1989): "The Effects of Salaries and Opportunity Costs on Duration in Teaching: Evidence from Michigan." *Review of Economics and Statistics,* 71(2), 347-52.

[50] Neal, Derek (2002): "How Vouchers Would Change the Market for Education," *Journal of Economic Perspectives*, 16:4, 25-44.

[51] Newey, Whitney and Daniel McFadden (1994): "Large sample estimation and hypothesis testing," in *Handbook of Econometrics*, Volume 4, 2111-2245.

[52] Ondrich, Jan, Emily Pas and John Yinger (2008): "The Determinants of Teacher Attrition in Upstate New York." Public Finance Review, 36(1), 112-44. Ortega, Daniel E. 2010. "The Effect of Wage Compression and Alternative Labor Market Opportunities on Teacher Quality in Venezuela." *Economics of Education Review*, 29(5), 760-71.

[53] Ortega, Daniel E. (2010): "The Effect of Wage Compression and Alternative Labor Market Opportunities on Teacher Quality in Venezuela." Economics of Education Review, 29(5), 760-71.

[54] Podgursky, M., R. Monroe and D. Watson (2004): “The Academic Quality of Public School Teachers: An Analysis of Entry and Exit Behavior." *Economics of Education Review*, 23(5), 507-18.

[55] Rees, D.I. (1991): "Grievance Procedure Strength and Teacher Quits." *Indus. & Lab. Rel. Rev.*, 45, 31.

[56] Richards, Craig E. and Tian Ming Sheu (1992): “The South Carolina School Incentive Reward Program: A Policy Analysis." *Economics of Education Review*, 11(1), 71-86.

[57] Rouse, Cecilia (1998): “Private School Vouchers and Student Achievement: The Effect of the Milwaukee Parental Choice Program," *Quarterly Journal of Economics*, 113:553-602.

[58] Sapelli, C. and B. Vial (2002), “The Performance of Private and Public Schools in the Chilean Voucher System," *Cuaderos de economia*, 39, 118, 423.

[59] Scafidi, Benjamin, David L. Sjoquist and Todd R. Stinebrickner (2006): “Do Teachers Really Leave for Higher Paying Jobs in Alternative Occupations?" *B.E. Journal of Economic Analysis and Policy: Advances in Economic Analysis and Policy*, 6(1), 1-42.

[60] Shin, Jaeun and Sangho Moon (2006): “Fertility, Relative Wages, and Labor Market Decisions: A Case of Female Teachers." *Economics of Education Review*, 25(6), 591-604.

[61] Stinebrickner, T.R. (1998): “An Empirical Investigation of Teacher Attrition." *Economics of Education Review*, 17(2), 127-36.

[62] Stinebrickner, Todd (2001): “Compensation Policies and Teacher Decisions," *International Economic Review*, 42:3.

[63] Stinebrickner, T.E. (2001b): “A Dynamic Model of Teacher Labor Supply," *Journal of Labor Economics*, 19(1), 196-230.

[64] Theobald, N.D. (1990): "An Examination of the Influence of Personal, Professional, and School District Characteristics on Public School Teacher Retention." Economics of Education Review, 9(3), 241-50.

[65] Theobald, Neil D. and R. Mark Gritz (1996): "The Effects of School District Spending Priorities on the Exit Paths of Beginning Teachers Leaving the District." Economics of Education Review, 15(1), 11-22.

[66] Tincani, M. (2012): "Optimal Teacher Policies: Estimating the Effects and Costs of Large-Scale Teacher Pay Schemes," mimeo, University College London.

[67] Tokman, Andrea Ramos (2002): "Is Private Education Better? Evidence from Chile," Working papers, Central Bank of Chile 147, Central Bank of Chile.

[68] Verhoogan, Eric and Miguel Urquiola (2009): "Class-Size Caps, Sorting, and the Regression-Discontinuity Design," *The American Economic Review*, Vol. 99, No. 1, pp. 179-215.

[69] Wolter, Stefan C. and Stefan Denzler (2004): "Wage Elasticity of the Teacher Supply in Switzerland." *Brussels Economic Review*, 47(3-4), 387-407.

[70] Yau, Jeffrey (2004): *Estimating the Impact of Vouchers when the Impact Depends on the Duration of Program Participation*, PhD Dissertation, University of Pennsylvania.

8 Appendix A: Estimation of the weighting matrix and of the limiting distribution

As noted in the text, for a general weighting matrix W, the method of moments estimator is distributed as

$$\sqrt{N}(\hat{\gamma} - \gamma) \sim (N(0, (\Gamma W \Gamma')^{-1}(\Gamma' W V W \Gamma)((\Gamma' W \Gamma')^{-1})').$$

For ease of exposition, in describing the construction of the variance-covariance matrix of the moments, V, consider a vector of a set of two moments corresponding to outcomes y_{ia}^1 and y_{ia}^2. The second moment uses observations for which $D_{i,Z'_{ia},\tilde{A}'} = 1$, which may overlap with the set of observations for which $D_{i,Z_{ia},\tilde{A}} = 1$.

$$f_N(\gamma) = \begin{bmatrix} \frac{1}{N}\sum_{i=1}^{N}\sum_{a=a_0}^{a'}(y_{ia}^1 - \hat{y}_{ia}^1(\gamma))D_{i,Z_{ia},\tilde{A}}w_i \\ \frac{1}{N}\sum_{i=1}^{N}\sum_{a=a_0}^{a'}(y_{ia}^2 - \hat{y}_{ia}^2(\gamma))D_{i,Z'_{ia},\tilde{A}'}w_i \end{bmatrix}.$$

To simplify the notation, we suppress the dependence of $\hat{y}$ on γ. A consistent estimator of the asymptotic variance-covariance matrix of the parameter estimates substitutes $\hat{V}_N$ and $\hat{\Gamma}_N$, where the estimator for V is:

$$\hat{V}_N = (\frac{1}{N})^2 \times \sum_{i=1}^{N_I}\sum_{a=a_0}^{a'}\sum_{l=a_0}^{a'}$$

$$\begin{bmatrix} (y_{ia}^1 - \hat{y}_{ia}^1)(y_{il}^1 - \hat{y}_{il}^1)D_{i,Z_{ia},\tilde{A}}D_{i,Z_{il},\tilde{A}}w_i^2 & (y_{ia}^1 - \hat{y}_{ia}^1)(y_{il}^2 - \hat{y}_{il}^2)D_{i,Z_{ia},\tilde{A}}D_{i,Z'_{il},\tilde{A}'}w_i^2 \\ (y_{ia}^2 - \hat{y}_{ia}^2)(y_{il}^1 - \hat{y}_{il}^1)D_{i,Z_{ia},\tilde{A}}D_{i,Z'_{il},\tilde{A}'}w_i^2 & (y_{ia}^2 - \hat{y}_{ia}^2)(y_{il}^2 - \hat{y}_{il}^2)D_{i,Z'_{ia},\tilde{A}'}D_{i,Z'_{il},\tilde{A}'}w_i^2 \end{bmatrix}$$

The off diagonal terms for any two moments that are based on different individuals (or different datasets) will be zero (i.e. zero covariance). For moments based in part on the same individuals, there are variance terms and covariance terms (capturing the correlations across ages).

The matrix Γ is the matrix of derivatives of each of the moments with respect to the model parameters. Let K denote the number of parameters (dimension of γ.) The dimensionality of Γ is $K \times m$. For example, for two moments, the Γ' matrix is

$$\Gamma' = \begin{bmatrix} \frac{\partial f_N^1(\gamma)}{\partial \gamma'} \\ \frac{\partial f_N^2(\gamma)}{\partial \gamma'} \end{bmatrix}_{2\times K}.$$

The derivatives that make up the elements of the Γ matrix are estimated by numerical derivatives. Let γ_i denote the ith element of γ and let Δ_i denote the same size vector Δ_i that is zero everywhere except in the ith element, which is a small positive number. Then the derivative of moment m with respect to γ_i is estimated by:

$$\frac{\widehat{\partial f_N^m(\gamma)}}{\partial \gamma_i} = \frac{f_N^m(\gamma + \Delta_i) - f_N^m(\gamma)}{\Delta_i}$$

The weighting matrix W is a diagonal matrix that does not depend on the parameter values. The diagonal elements are chosen to make the magnitude of the different moments roughly comparable. Specifically, we compute the mean of the outcome to which each moment refers and use one over the mean as the weight. For example, for wages in a given sector, we compute the average wage in that sector (for people who actually work in that sector) and the weight is one over the mean. A similar weight is used for the moments representing proportions.

9 Appendix B: Moments used in estimation

To use separate simulation algorithms and separate state spaces, we separate the EPS dataset into certified teachers (EPSt) and non-teachers (EPSnt). EPSnt has a sample size of 697 and a total number of person-year observations of 6,841.

9.1 Moments using data from age a_{G+1} to age a_R

Moments from the age of graduation/certification (a_{G+1}) to the age of retirement (a^R) refer to outcomes and choices subsequent to the decision on whether to get a teaching degree. The options for certified and non-certified teachers are different (non-certified teachers cannot teach), hence the algorithm that simulates one-step ahead forecasts is different for certified-teachers and non-teachers. Moreover, simulations are conditional on the state space, which is different for different individuals.

Because of the different problems that certified teachers and non-teachers solve, we match different moments to the different datasets: ELD, EPSt and EPSnt. In all three datasets we only use cells that contain at least 20 observations. A cell is defined by the value of the variables that the moment is conditioned on, so for instance the size of the cell "outcome1 by gender = female" is the number of women for whom we have both a real outcome1 and a simulated outcome1. A simulated outcome exists if and only if all the variables in the current state space are non-missing.

We grouped together cells for which there were too few observations in a way that maintained variation, so for example if there were 3 age categories, we would not group together all three age categories, because by doing so we would lose the age variation.

9.1.1 Moments based on the ELD dataset

We match 229 moments to the ELD. We never use the year after they initially become certified to teach (which is why age starts at 23 and not at 22). The following are the categories used in constructing the moments based on the ELD data:

$$\text{agecat1} = \begin{cases} 1 & \text{if } age \in [23, 34] \\ 2 & \text{if } age \in [35, 44] \\ 3 & \text{if } age \in [45, 54] \end{cases}$$

The following is used only for the fertility moment, in all other cases we use the same categories for females and males. agecat1males= $\begin{cases} 1 & \text{if } agecat1 = 1 \text{ or } agecat1 = 2 \\ 2 & \text{if } agecat1 = 3 \end{cases}$

agecat2= $\begin{cases} 1 & \text{if } age \in [23, 29] \\ 2 & \text{if } age \in [30, 34] \\ 3 & \text{if } age \in [35, 44] \\ 4 & \text{if } age \in [45, 54] \end{cases}$

texpcat= $\begin{cases} 1 & \text{if } texp \in [0, 4] \\ 2 & \text{if } texp \in [5, 9] \\ 3 & \text{if } texp \in [10, 14] \\ 4 & \text{if } texp \in [15, 19] \end{cases}$

nkidscat is equal to the number of children if this is equal 0, 1 or 2. If the number of children is 3 or above, then nkidscat=3. (In the data, there are at most 4 children per individual).

The sectors for which we have wages in the ELD data are: municipal school, private unsubsidized school and private subsidized school. No wages are available for the non-teaching sector.

We match squared wages because we truncated outliers in the wage distribution. Matching wage variances would be unfeasible because it would introduce a dependence across individuals that would make the estimation of the variance/covariance matrix of the moments too costly computationally.

List of moments:

(i) wage and wage squared by sector, agecat1, gender

(ii) wage and wage squared by sector, texpcat and gender

(iii) wage and wage squared by sector, nkidscat and gender

(iv) fractions in sectors M, V, U by texpcat and gender[46]

(v) fractions in sectors M, V, U by nkidscat and gender

(vi) fractions in sectors M, V, U by agecat2 and gender

(vii) fraction of individuals working in a teaching occupation who are laid off by texpcat

(viii) fraction of females who have a child by agecat1, nkidscat, whether they had a child in the previous period (up to age 44)

[46] We don't match fractions in NT and H because there are too few observations.

(ix) fraction of males who have a child by agecat1males, nkidscat, whether they had a child in the previous period (up to age 49)

(x) transition probabilities from sectors M V U to sectors M V U by gender (we don't match transitions from and to sectors NT and H because there are too few observations)

9.1.2 Moments using the EPSnt (EPS-non-teacher) dataset

We match 106 moments to the EPSnt. The following are the EPSnt categories used in constructing the moments:

$$\text{agecat1}=\begin{cases} 1 & \text{if } age\in[22,34] \\ 2 & \text{if } age\in[35,44] \\ 3 & \text{if } age\in[45,54] \end{cases}$$

$$\text{agecat2}=\begin{cases} 1 & \text{if } age\in[22,29] \\ 2 & \text{if } age\in[30,34] \\ 3 & \text{if } age\in[35,44] \\ 4 & \text{if } age\in[45,54] \end{cases}$$

$$\text{ntexpcat}=\begin{cases} 1 & \text{if } ntexp\in[0,4] \\ 2 & \text{if } ntexp\in[5,9] \\ 3 & \text{if } ntexp\in[10,14] \\ 4 & \text{if } ntexp\in[15,19] \end{cases}$$

nkidscat is equal to the number of children if this is equal 0, 1 or 2. If the number of children is 3 or above, then nkidscat=3. (In the data, there are at most 5 children per individual).

Wages are available only for the non-teaching occupation, as the individuals in EPSnt cannot teach.

The following is a list of EPSnt moments used in estimation:

(i) wage and wage squared by agecat1 and gender

(ii) wage and wage squared by ntexpcat and gender

(iii) wage and wage squared by nkidscat and gender

(iv) fraction in sector NT by ntexpcat and gender

(v) fraction in sector NT by nkidscat and gender

(vi) fraction in sector NT by agecat2 and gender

(vii) fraction of individuals working in a non-teaching occupation laid off by ntexpcat

(vii) fraction of individuals who have a child by gender, agecat2, nkidscat and whether they had a child the previous period (up to age 44 for female and 49 for males)

(viii) persistence in sectors NT and H by gender[47]

Moments using data from a_G:

In the first period of the model, at the age of graduation/certification (a_G), individuals choose between a teaching certification and getting a non-teaching college degree. We match two moments:

(ix) the fraction of males who get certified

(x) the fraction of females who get certified

using the EPS data.[48]

9.2 Structure of the variance covariance matrix of the moment conditions

The variance covariance matrix V, used in the computation of the parameter standard errors, is a square symmetric matrix with a number of rows equal to the total number of moments matched, 337. Because the individuals in ELD and EPS are different, there is no covariance between the moments pertaining to individuals from different datasets. Hence V is a block diagonal matrix with two block matrices on the diagonal: one corresponding to the EPS moments (V_{EPS}) and one corresponding to the ELD moments (V_{ELD}).

The matrix V_{EPS}, occupying rows and columns 1 to 108 of V, contains the variance of the moments relative to the choices of non-teachers (EPSnt) from time period 1 onwards, the variance of the moments relative to the choice of certification at time 0, and their covariances. Rows and columns 109 to 337 contain V_{ELD}, the matrix of the moments relative to the choices of teachers (ELD) from time period 1 onwards.

[47] We match only persistence because transition to the other sector is defined residually.

[48] The fraction getting certified is not observed in the ELD dataset, which only contains information on teachers.

Table 1
Parameter Estimates
(T-statistics in parentheses)

Utility of Obtaining an Education Degree	Estimate	T-statistic
Type 1 - λ_{01}	-2.610 x E08	(-1.36E+01)
Type 2 - λ_{02}	-8.011 x E07	(-9.73E+00)
Type 3- λ_{03}	-9.821 x E07	(-8.46E+00)
Female - λ_{1}	6.390 x E07	(1.11E+01)
Age at graduation/cert - λ_{2}	1.280 x E06	(1.10E+01)
Std. dev. - σ_{η}	1.856 x E01	(6.73E+01)

Payoff: Municipal Schools	Estimate	T-statistic
Constant term - $\alpha^{M}{}_{0}$	15.00	(2.93E+03)
Experience - $\alpha^{M}{}_{1}$	0.025	(1.45E+01)
Experience squared - $\alpha^{M}{}_{2}$	-0.0015	(-1.11E+01)
Nonpec., type 1 - $\beta^{M}{}_{01}$	-3.975 x E06	(-1.18E+01)
Nonpec., type 2 - $\beta^{M}{}_{02}$	4.973 x E06	(1.10E+01)
Nonpec. Type 3 - $\beta^{M}{}_{03}$	1.235 x E06	(1.25E+01)

Payoff: Voucher Schools	Estimate	T-statistic
Type 1 - $\alpha^{V}{}_{01}$	14.88	(1.70E+01)
Type 2 - $\alpha^{V}{}_{02}$	17.03	(3.13E+02)
Type 3 - $\alpha^{V}{}_{03}$	15.06	(2.45E+03)

Payoff: Non-Teaching Sector	Estimate	T-statistic
Type 1 - $\alpha^{NT}{}_{01}$	14.95	(2.27E+02)
Type 2 - $\alpha^{NT}{}_{02}$	15.93	(1.30E+02)
Type 3 - $\alpha^{NT}{}_{03}$	15.51	(8.55E+02)
Teaching Experience - $\alpha^{NT}{}_{1}$	0.028	(1.30E+01)
Nonteaching Experience - $\alpha^{NT}{}_{2}$	0.055	(1.08E+01)
Nonteaching Exp squared - $\alpha^{NT}{}_{3}$	-0.00243	(-9.43E+00)
Has an education degree - $\alpha^{NT}{}_{4}$	-0.176	(-9.70E+00)
Female - $\alpha^{NT}{}_{5}$	-0.286	(-1.78E+01)

Payoff: Home Sector	Estimate	T-statistic
Type 1 - $\beta^{H}{}_{01}$	1.301 x E06	(1.03E+01)
Type 2 - $\beta^{H}{}_{02}$	-1.465 x E08	(-9.53E+00)
Type 3 - $\beta^{H}{}_{03}$	3.947 x E05	(1.06E+01)
Number of children *age < 51 -$\beta^{H}{}_{1}$	3.120 x E05	(1.17E+01)
Number of children *female * age < 51 - $\beta^{H}{}_{2}$	1.120 x E05	(8.66E+00)

Transition Costs	Estimate	T-statistic
Switching sectors, not at home last period-c^{s}	-2.524 x E08	(-8.07E+00)
Laid off - c^{l}	-2.394 x E07	(-1.05E+01)
Home last period - c^{w}	-7.598 x E06	(-1.44E+01)

Experience - α^V_1	0.054
	(1.72E+01)
Experience squared α^V_2	-0.00144
	(-1.05E+01)
Female - α^V_3	-0.105
	(-2.99E+01)
Nonpec., type 1 - β^V_{01}	-4.891 x E07
	(-9.15E+00)
Nonpec., type 2 - β^V_{02}	-2.688 x E07
	(-1.18E+01)
Nonpec., type 3 - β^V_{03}	8.255 x E05
	(9.35E+00)

Payoff: Unsubsidized Schools	
Type 1 - α^U_{01}	14.90
	(1.52E+01)
Type 2 - α^U_{02}	16.70
	(3.27E+02)
Type 3 - α^U_{03}	15.16
	(2.80E+03)
Experience - α^U_1	0.075
	(3.66E+01)
Experience squared - α^U_2	-0.0020
	(-1.67E+01)
Female - α^U_3	-0.078
	(-1.33E+01)
Nonpec. type 1 - β^U_{01}	-3.081 x E07
	(-1.57E+01)
Nonpec. type 2 - β^U_{02}	-3.139 x E07
	(-1.24E+01)
Nonpec. type 3 - β^U_{03}	-2.804 x E05
	(-1.32E+01)

Log of the Std. dev. of Payoffs	
Municipal sector - σ^M	-3.47E-01
	(-1.05E+01)
Voucher sector - σ^V	-2.70E-01
	(-1.36E+01)
Unsubsidized sector - σ^U	-7.65E-01
	(-9.99E+00)
Nonteaching sector - σ^{NT}	-1.19E-01
	(-7.98E+00)
Home sector - σ^H	1.34E+01
	(2.75E+01)

Fertility Process	
Type 1 - γ^f_{01}	-9.25
	(-1.11E+01)
Type 2 - γ^f_{02}	-9.49
	(-9.50E+00)
Type 3 - γ^f_{03}	-0.468
	(-1.14E+01)
Age - γ^f_1	0.049
	(1.16E+01)
Age squared - γ^f_2	-0.003
	(-2.35E+01)
Age * female - γ^f_3	-0.012
	(-1.11E+01)
Number of children - γ^f_4	0.233
	(1.21E+01)
Birth last period - γ^f_5	-1.312
	(-9.98E+00)

Dismissal Process	
Constant - γ^{IT}_0	-2.904
	(-1.97E+01)
Teaching experience - γ^{IT}_1	-0.148
	(-9.47E+00)
Constant - γ^{INT}_0	-2.197
	(-2.60E+01)
Non-teaching experience - γ^{INT}_1	-0.082
	(-1.03E+01)

Probability of Type 2		Probability of Type 3	
Constant – ω_{20}	-2.465 (-1.39E+01)	Constant – ω_{30}	-0.243 (-9.28E+00)
Female - ω_{21}	-1.250 (-1.04E+01)	Female - ω_{31}	0.035 (9.55E+00)
Teaching experience - ω_{22}	-1.564 (-1.08E+01)	Teaching experience - ω_{23}	0.105 (1.16E+01)
Teaching exp squared - ω_{23}	0.135 (1.13E+01)	Teaching exp squared - ω_{33}	0.083 (1.26E+01)
Number of children - ω_{24}	0.793 (9.01E+00)	Number of children - ω_{34}	2.739 (1.16E+01)
Non-teaching sector last period - ω_{25}	-0.711 (-9.90E+00)	Non-teaching sector last period - ω_{35}	-0.566 (-1.00E+01)
Laid off from teaching last period - ω_{26}	5.840000 (1.02E+01)	Laid off from teaching last period - ω_{36}	-9.350 (-1.12E+01)
Age at graduation/certification - ω_{27}	-0.0056 (-9.05E+00)	Age at graduation/certification - ω_{37}	-0.080 (-1.06E+01)
Birth last period - ω_{28}	1.630 (1.26E+01)	Birth last period - ω_{38}	-2.500 (-1.01E+01)
In ELD sample - ω_{ELD}	0.315 (1.46E+01)	In ELD sample - ω_{ELD}	5.803 (1.52E+01)

Table 2
Model Fit

	Actual	Model
Proportion With Education Degree		
Female	.178	.177
Male	.061	.062
Proportion of Teachers Employed in:		
Municipal Schools		
Female	.338	.348
Male	.296	.318
Voucher Schools		
Female	.483	.506
Male	.482	.512
Unsubsidized Schools		
Female	.118	.124
Male	.140	.150
Non-Teaching Jobs		
Female	.022	.014
Male	.041	.013
Proportion of Non-Teachers Employed		
Female	.757	.785
Male	.852	.885
Mean Accepted Wage[1]: Teachers		
Municipal Schools		
Female	5118	5358
Male	5550	5470
Voucher Schools		
Female	5749	6255
Male	6585	6874
Unsubsidized Schools		
Female	6670	7044
Male	7431	7717
Mean Accepted Wage[1]: Non-Teachers		
Female	5905	5928
Male	8458	8288

1. In 1,000's pesos.

Table 3

	Females			Males		
	Type 1	Type 2	Type 3	Type 1	Type 2	Type 3
Population Proportion	.730	.018	.253	.721	.059	.221
Proportion Given an Education Degree	.184	.090	.726	.060	.450	.490
Proportion Given a Non-Education Degree	.847	.002	.151	.764	.033	.203

Table 4
Counterfactual Policies

	Baseline			Bonus to Education Degree: Two Years of Municipal Wages			20% Increase in Municipal Wage			Municipal Schools Adopt Voucher School Wage Function			Eliminate Voucher Schools		
	All	Fem.	Male	All	Fem.	Male	All	Fem.	Male	All	Fem.	Male	All	Fem.	Male
Prop. with Education Degree	.121	.177	.062	.128	.187	.067	.136	.199	.070	.137	.178	.095	.104	.166	.038
Proportion given Education Degree of															
Type 1	.153	.184	.060	.161	.193	.067	.179	.213	.078	.131	.178	.038	.186	.204	.103
Type 2	.180	.090	.450	.176	.086	.440	.160	.080	.397	.273	.099	.615	.065	.049	.140
Type 3	.667	.726	.490	.663	.721	.494	.661	.707	.524	.596	.723	.347	.759	.747	.757
Proportion Working in Municipal Schools of															
Type 1	.014	.013	.049	.015	.013	.047	.215	.226	.147	.001	.000	.001	.021	.019	.030
Type 2	.000	.000	.000	.000	.000	.000	.002	.002	.000	.530	.253	.794	.117	.078	.312
Type 3	.986	.987	.951	.985	.987	.953	.783	.772	.853	.469	.747	.205	.862	.903	.658
Proportion Working in Voucher Schools of															
Type 1	.001	.002	.000	.001	.002	.000	.000	.001	.000	.013	.015	.001	.000	.000	.000
Type 2	.572	.449	.688	.563	.438	.677	.976	.983	.971	.006	.001	.031	.000	.000	.000
Type 3	.427	.549	.312	.436	.560	.323	.024	.016	.029	.981	.984	.968	.000	.000	.000
Proportion Working in Unsubsidized Schools of															
Type 1	.037	.050	.003	.036	.050	.003	.240	.278	.000	.125	.135	.021	.018	.047	.001
Type 2	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Type 3	.963	.950	.997	.964	.950	.997	.760	.722	1.00	.875	.865	.979	.982	.953	.999