

# Teacher Quality in Public and Private Schools Under a Voucher System: The Case of Chile

Jere R. Behrman, Michela M. Tincani, Petra E. Todd, Kenneth I. Wolpin <sup>1</sup>

August, 2013, revised May, 2014

<sup>1</sup>Jere R. Behrman is W.R. Kenan Jr. Professor of Economics and Sociology and a PSC Research Associate at the University of Pennsylvania. Michela M. Tincani is a post-doctoral research fellow at University College London and a Research Affiliate at IFS and CeMMAP. 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 at the University of Pennsylvania 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. A key criticism of school voucher systems is that they make it easier for private schools to attract better teachers to the detriment of public schools. This paper uses longitudinal household and teacher survey 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. Empirical results show support for the concern that private voucher schools attract better teachers than public schools. However, the existence of the private voucher sector also draws higher productivity individuals into the teaching profession.

# 1 Introduction

In 1981, Chile adopted an innovative nationwide school voucher system for primary and secondary education that still operates today.<sup>1</sup> 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 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 2007), 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 2004, 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 all schools.<sup>2</sup> 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.<sup>3</sup> Private non-subsidized schools, which include both religious (mainly Catholic) and lay schools, are financed from private tuition.<sup>4</sup> Parents are free to choose among municipal and both types of private schools.<sup>5</sup>

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

---

<sup>1</sup>The voucher reform was one of several privatization and decentralization efforts introduced by Augusto Pinochet's military government.

<sup>2</sup>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 Verhoogen and Urquiola, 2009.

<sup>3</sup>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.

<sup>4</sup>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).

<sup>5</sup>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 student's test score performance at 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, 2014, Bravo, Contreras and Sanhueza, 1999, Vegas, 2002) 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.<sup>6</sup>

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.<sup>7</sup> 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.<sup>8</sup> After the restoration of the democratic 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 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 in the United

---

<sup>6</sup>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.

<sup>7</sup>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.

<sup>8</sup>Carnoy (1997).

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 choice of sector in which to work, 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 Stinebrickner (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.<sup>9</sup> 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 nonsubsidized 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 working decisions, 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 preferences using the Keane-Wolpin (1997)

---

<sup>9</sup>In Chile, teacher certification is required to work in any type of school.

multinomial types approach.<sup>10</sup>

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.<sup>11</sup> 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 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 only use the longitudinal information for the 690 "non-teachers" in estimating the model.

For 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 of 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.<sup>12</sup> 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 moments. This estimation procedure permits combining moments from our different data sources

---

<sup>10</sup>The approach is similar to Heckman and Singer's (1984) use of discrete types to control in duration analysis.

<sup>11</sup>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.

<sup>12</sup>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.

(the EPS and the ELD datasets).<sup>13</sup> 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 that receive higher wage offers, 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 attracts lower productivity types into the teaching profession.<sup>14</sup>

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. Our 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.

The paper proceeds as follows. 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. Section six presents the parameter estimates and results based on model simulations.

---

<sup>13</sup>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.

<sup>14</sup>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 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. We also briefly summarize a related literature on the effects of school voucher systems on the productivity of private and public schools.

### 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. 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.<sup>15</sup> 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

---

<sup>15</sup>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.<sup>16</sup> 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),

---

<sup>16</sup>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.<sup>17</sup>

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%, 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

---

<sup>17</sup>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.<sup>18</sup>

Wiswall (2007) extends Stinebrickner (2001s) occupational choice model to allow for a preliminary stage in which potential teachers decide whether to obtain certification. He estimates a dynamic discrete choice model that he uses to analyze the effects of changes in teacher licensing policy. He finds that more stringent licensing rules reduce teacher labor supply and average teacher quality.

Dolton and van der Klaauw (1995, 1999) analyze decisions to leave the teaching profession within a competing risks framework.<sup>19</sup> 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

---

<sup>18</sup>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.

<sup>19</sup>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.

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 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 (2014) 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 (2014), the current 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 (2014) uses a static model. Parameter estimates are unaffected by the fact that parental behavior is not modeled. Preferences over student characteristics are captured in the model by sector-specific non-pecuniary preference parameters. Sector-specific wage parameters, which are used to infer productivity, are also estimated without bias given that the model accounts for self-selection into sectors.

## **2.4 Effects of voucher systems on school productivity**

There is a growing literature analyzing the effects of voucher reforms on productivity in public and private schools. Bohlmark and Lindahl (2008) analyze the effects of voucher reform introduced in Sweden in 1992. Prior to that time, public schools were virtually the only type of school available. The reform increased the availability of private schools with the degree of privatization varying significantly across municipalities and over time. Bohlmark and Lindahl (2008) use a difference-in-difference strategy comparing outcomes for cohorts who were exposed and not exposed to the reform and living in municipalities with and without private schools, focussing on 9th grade students. They find significant short-term effects of private school enrollment over the short-term on 9th grade GPA and on the fraction of students choosing the academic high school track but no longer term effects. Sandström and Bergström (2005) also analyze effects of competition on public schools using Swedish data and using a sample selection model to take into account endogeneity of the choice of school type. The study finds that private school competition promotes improvement in public schools on nationwide standardized test and higher average grades.

A few papers examine the effects of new tuition tax credit policies that effectively reduce the relative price of private schools. Figlio and Hart (2014) examines effects of a means-tested tax credit, the Florida Tax Credit, introduced in 2001. They use a difference-in-difference strategy that compares the change in test scores in public schools in areas that had a high or low degree of private school penetration when the tax credit was introduced. The study finds modestly higher test scores for public school students stemming from increased competition. Chan (2009) uses a similar empirical strategy in analyzing the effects of the 2002 Ontario tuition tax credit, which increased access to private schools throughout Ontario. Also using a difference-in-difference analysis, the study finds that public schools that faced a greater degree of competition from private schools

experienced greater gains in students' test passing rates.

A study by Card, Dooley and Payne (2008) uses data from Ontario, Canada to examine whether a higher degree of competition between the public school system and a Catholic school system that receives equal public funding leads to improved productivity, as measured by test score gains between third and sixth grade. In particular, it looks at how test scores respond to local school openings. The paper estimates a significant but modest-sized impact of competition on the growth rate of student achievement and that extending competition to all students would increase average test scores by 6-8% of a standard deviation. Gibbons, Silva and Machin (2008) analyzes whether a higher degree of school choice or school competition improves educational outcomes using administrative data on students in primary schools in South East England. Using an IV strategy to address concerns about potential nonrandom sorting of pupils or schools, they find no evidence for a relationship between choice or competition and educational outcomes. However, they find that a certain type of schools (called Voluntary Aided schools) experience better outcomes when there is a higher degree of local school competition. West and Woessmann (2010) use student-level data from 29 countries to analyze whether the share of students in private schools leads to higher achievement on the PISA mathematics, science and reading exams. Their empirical approach uses historical shares of Catholics living in the country at the end of the nineteenth century as an instrument for the share of private schools today. They find that the share of private schools significantly affects student achievement. Also, much of the positive effect is observed for students attending public schools, suggesting that the benefit comes through increased competition.

There are a few studies examining the relationship between test score performance and private school competition using Chilean data. Gallego (2002) examines changes in SIMCE national standardized test scores between 1994 and 1997 and finds that competition has a positive effect on educational achievement in general, but also that the private subsidized schools attract and accept only the academically better students. Auguste and Valenzuela (2003) analyze the relationship between test scores (in the year 2000) and school competition, using an instrumental variables approach to address the potential endogeneity of the school competition measure; they find that more competition increases test scores.<sup>20</sup> However, Hsieh and Urquiola (2006) reach a different

---

<sup>20</sup>Community population and distance to the closest city serve as instruments.

conclusion based on a comparison of average test scores in communities that experienced a greater or lesser increase in private school enrollment. Using community-level data, they find that average standardized test scores did not rise faster in communities where private sector enrollment expanded more. Rather, average repetition and grade-for-age worsened in such areas relative to other communities.<sup>21</sup>

Vegas (2002) uses a data set of teachers in Santiago, Chile that was collected in 1998-99 that provides information on teacher characteristics and on teachers' perceptions of the schools in which they work and on school management. The teacher data are merged with school-level data on student achievement from national assessment data (the SIMCE data). She finds that differences within sectors in student outcomes and student background and in teacher characteristics are greater than differences between sectors and that a great deal of the variation in student outcomes is unexplained. She finds teacher education, decentralization of decision-making and teacher autonomy to be important factors in explaining student outcomes.

### 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 layoffs. 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.<sup>22</sup>

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 who have

---

<sup>21</sup>A potential limitation of the analysis is that it examines differences in test scores over time, though the SIMCE tests were not comparable over time prior to 1998, when test equating was introduced.

<sup>22</sup>Teaching in Chile requires a college degree. Additional sample restrictions are described in detail below.

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.<sup>23</sup> 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.<sup>24</sup>

Teaching and non-teaching experience accumulate endogenously in the model. Modeling the endogenous evolution of teaching and non-teaching experience separately is necessary because the teaching wages depend on teaching experience.<sup>25</sup> The initial conditions of the model are gender, the age at which individuals are certified to teach,  $a_i^G \in \{22, 23, \dots, 40\}$ , 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.<sup>26</sup>

---

<sup>23</sup>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 2.3 years of non-teaching experience. In estimation, we set their non-teaching experience at certification to zero.

<sup>24</sup>We assume that the value function is zero after retirement. In principle different retirement schemes in private and public schools may affect the sectoral choices. However, our sample of teachers is comprised of young cohorts and, because of discounting, the effect of introducing different retirement schemes will likely be small.

<sup>25</sup>We do not model accumulation of teaching experience by sector separately because in Chile the law states that teaching experience is rewarded by municipal school wages independently of the school sector in which that teaching experience was accumulated.

<sup>26</sup>The types introduce a dimensionality reduction that allow us to identify productivity in different sectors without relying only on the individuals who are observed in multiple sectors, as would be necessary if we estimated a person and sector specific fixed effect. See Keane and Wolpin (1997).



### 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).<sup>27</sup> The flow utilities associated with the education (E) and the non-teaching options (NE) are:

$$\begin{aligned} U_{ia^G}^E &= \sum_k \lambda_{0k}^E I(\text{type}_i = k) + \lambda_1^E D_i^f + \lambda_2^E a_i^G + \eta_i^E \\ U_{ia^G}^{NE} &= 0, \end{aligned}$$

where  $I(\text{type} = k)$  is an indicator equal to one if the individual is of type  $k$  and  $D_i^f$  is a dummy variable that equals 1 if female.<sup>28</sup> It is assumed that the preference shock follows a normal distribution,  $\eta_i^E \sim N(0, \sigma_\eta^2)$ .

### 3.2 Sector decisions

Individuals who earn an education degree choose in subsequent periods (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  $d_{ia}^{(1)} = 1$  if M is chosen by individual  $i$  at age  $a$  (and zero otherwise),  $d_{ia}^{(2)} = 1$  if V is chosen (and zero otherwise),  $d_{ia}^{(3)} = 1$  if U is chosen (and zero otherwise),  $d_{ia}^{(4)} = 1$  if NT is chosen (and zero otherwise) and  $d_{ia}^{(5)} = 1$  if H is chosen (and zero otherwise).

Period-specific utilities associated with working depend on wages as well as on nonpecuniary factors.<sup>29</sup> The wage offer schedule in the municipal sector depends only on total teaching experience,

---

<sup>27</sup>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 + 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.

<sup>28</sup>The utility for the non-education option is normalized to zero because only the difference in utilities can be identified.

<sup>29</sup>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.

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

$$\ln(w_{ia}^M) = \alpha_0^M + \alpha_1^M tx_{ia} + \alpha_2^M tx_{ia}^2 + \epsilon_{ia}^M$$

where  $w_{ia}^M$  is the wage offer to individual  $i$  of age  $a$  and  $tx_{ia}$  is individual  $i$ 's total teaching experience (across all teaching sectors). Unobserved skill endowments and gender variables do not enter the municipal wage equation to reflect the institutional feature that municipal wages are centrally determined by the Chilean Teacher's Statute and do not vary by productivity nor gender. The unobserved component of the wage offer,  $\epsilon_{ia}^M$ , reflects some adjustments to wages that depend on factors such as working conditions and managerial responsibilities.<sup>30</sup>

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,  $\epsilon_{ia}^j$ ,  $j = V, U$ . 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,  $\epsilon_{ia}^{NT}$ . Wage offers in these sectors

---

<sup>30</sup>Bravo et al. (2010) contains a detailed description of the actual municipal wage formulae from the *Estatuto Docente*. Consistent with our model, gender does not enter the wage and years of teaching experience do not depend on the sector in which that experience was accumulated. On top of the teaching experience bonus, which is the largest bonus, there are around twenty other types of bonuses that depend on variables that are not observed in our dataset. They are not included in our wage equation for data limitations. The shock in our wage equation is an approximation error that captures these bonuses. Examples of these bonuses are those related to managerial responsibilities, to teaching special types of courses, and to teaching in schools with more than 250 students. The  $R^2$  for the variables used as moments in the estimation,  $wage_j \times D_j$ ,  $j \in \{M, V, U\}$  where  $D_j$  is a dummy equal to 1 if sector  $j$  is chosen, and equal to 0 otherwise, represents a lower bound for the  $R^2$  of the fit of the accepted wage. The fit in municipal schools - where unobserved heterogeneity is not allowed to enter the wage equation - is similar (slightly better) than the fit in private unsubsidized and subsidized schools. Specifically, the  $R^2$  for municipal schools is .83, for voucher schools it is .82, and for private unsubsidized schools it is .81. This suggests that the assumed municipal wage equation is a good approximation to the governmental formulae.

are given by

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

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.<sup>31</sup>

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  $k \in 1, 2, \dots, K$  are:

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

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  $\beta_{0k}^j$  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:

$$U_{ia}^H = \sum_k \beta_{0k}^H + \beta_1^H nk_{ia} I(a_i \leq 50) + \beta_2^H nk_{ia} D_i^f I(a_i \leq 50) + \eta_{ia}^H,$$

---

<sup>31</sup>Like in a classical Ben-Porath framework (Ben-Porath, 1967), the wages reflect the product of skills and the price of those skills. Under the normalization of skill prices, the constants in the log-wages are identified up to scale (see, for example, Heckman and Sedlacek, 1985). Therefore, it is possible to rank types in terms of sector-specific productivity, as we do in the section with the empirical results.

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.<sup>32</sup> 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 ( $D_{i,a-1}^b$ ).<sup>33</sup> It is specified as a logit,

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

As in the case of fertility, 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.<sup>34</sup> The probability of dismissal/nonrenewal for a teacher,  $p_{ia}^{IT}$ , is given by

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

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,  $p_{ia}^{INT}$ , is given by

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

---

<sup>32</sup>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.

<sup>33</sup>Births are unlikely to occur in consecutive years.

<sup>34</sup>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.

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,  $\Omega_{ia}$ .<sup>35</sup>

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

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  $\Omega_{ia} = [1 \quad D_i^f \quad tx_{ia} \quad ntx_{ia} \quad nk_{ia} \quad d_{i,a-1} \quad D_{i,a}^l \quad D_i^e \quad a_i^G \quad D_{i,a-1}^b]'$ .<sup>36</sup>

Specifically, in the above expression,

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

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 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.

---

<sup>35</sup>We do not allow types to change over time: types capture permanent unobserved heterogeneity. The reason that the type probabilities depend on time-varying variables is because of individuals' self-selection. Individuals are making choices over time that endogenously determine which point in the state space they reach in each time period. Therefore, the distribution of unobserved types across the state space varies over time. To capture this, as an approximation, we let the type probability depend on time-varying state variables.

<sup>36</sup>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  $\gamma$ , 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  $\delta$  is the discount factor and  $a_R$  is the age of retirement. In the last decision period, the future Emax is set to 0. 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 model parameters using a conditional simulated methods of moments approach.<sup>37</sup> 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  $\Omega_{ia}$  denote the state space of individual  $i$  at age  $a$ , where  $i = 1, \dots, N_I$ ,  $\omega_{ia} \in \Omega_{ia}$  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.  $\hat{y}_{iask}(\gamma)$  denotes the predicted value of  $y_{ia}$  given model parameters  $\gamma$ , for simulation number  $s$  (where  $s = 1, \dots, S$ ) and an individual of type  $k$ , where  $k \in \{1, \dots, K\}$ . 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,

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

---

<sup>37</sup>See, e.g., Gouieroux and Monfort, 2002.

where  $Pr(\text{type}_i = k|\Omega_a)$  integrates to one and, as noted, is 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 probability (divided by 100) of making the choice of 1 (e.g. 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 private school teachers. 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 in the two datasets to reweight the observations back to random sampling proportions.<sup>38</sup> 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.<sup>39</sup> 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.<sup>40</sup>

We can write the  $i$ th moment condition as <sup>41</sup>

---

<sup>38</sup>Recall that we also account for potential sample selection based on unobservables through the inclusion of an ELD indicator variable in the type probability function.

<sup>39</sup>The weights are 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.

<sup>40</sup>For ease of notation, we abstract from possibly having an unbalanced panel.

<sup>41</sup>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 municipal sector wages. The corresponding moment condition is

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

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

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

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

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

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  $\Gamma$ ,  $V$ , 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,

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

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 *Estatuto 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.<sup>42</sup> 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

---

<sup>42</sup>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.

## 6 Empirical Results

### 6.1 Parameter estimates

Table 1 shows the estimated model parameters.<sup>43</sup> 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  $\beta_{0j}^M$ '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 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 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

---

<sup>43</sup>Because of the relatively short panel, we did not estimate the discount factor, which was set at 0.96.

all of the other sectors. We therefore interpret type 1's as the lowest productivity type and type 2 as the highest.

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, more so 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 Discussion: types and teacher productivity

As noted in, for example, Hanushek and Rivkin (2006), the literature on the estimation of cognitive achievement production functions has developed mostly separately from the literature on teacher labor supply: the studies that estimate teacher effectiveness from data on student test scores abstract from teacher labor supply decisions, and vice-versa. Within the teacher labor supply literature, different studies have used different measures of teacher quality, e.g. teacher experience, qualifications, measures of teacher cognitive skills. In this paper, we use teacher productivity as valued by the labor market to measure teacher quality, and we examine how productivity varies by unobserved (and observed) teacher characteristics. This is important, because studies using test scores to estimate teacher quality find that it varies substantially among teachers, and that it is related to unobserved teacher characteristics (see e.g. Rivkin et al, 2005).

We study how opportunity wages in non-teaching occupations affect the decision to enter and stay in the teaching profession, because previous studies show that wages in the non-teaching sector are an important determinant of the decision to become a teacher (e.g. Dolton and Van der Klaauw 1999). We adopt a rich framework in which we allow productivity in the non-teaching sector to differ from productivity in the teaching sector. Our estimation results show that individuals who are more productive in the non-teaching sector are also more productive in the teaching sector. This is consistent with previous studies that found that increasing non-teaching sector wages reduces the quality of the teaching force (e.g. Corcoran et al., 2004).

In the context of Chile, Tincani (2014) finds that the measure of teacher productivity we use affects student test scores positively; types who obtain higher wages in private schools increase student test scores by more. Bravo et al. (2010) find that private school teacher wages increase with teacher cognitive skills, as measured by the teacher's PAA score (*Prueba de Aptitud Académica*, the Chilean equivalent of the SAT score), and that teachers' PAA scores are positively correlated with student test scores. Finally, Correa et al. (2014) find positive selection of teachers into private schools using a Roy model (Roy, 1951), where, like in this paper, teacher quality is measured by labor market productivity.

### 6.3 Descriptive statistics and model fit

Tables 2 and 3 present descriptive statistics and evidence on the model fit, based on one-step-ahead simulations.<sup>44</sup> 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.<sup>45</sup> 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.<sup>46</sup>

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

---

<sup>44</sup>The means shown in the table incorporate sampling weights.

<sup>45</sup>The simulations are based on 40 simulation draws.

<sup>46</sup>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.

## 6.4 Policy simulations

In all simulations we assume that the market for teachers is competitive and that all teachers teach if they want to at equilibrium wages. 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.<sup>47</sup> 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 private voucher sector.<sup>48</sup> 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.<sup>49</sup> 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.<sup>50</sup>

The columns under "Baseline" show the type distributions based on the model estimates. As seen, in the baseline, 12.1 percent 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

---

<sup>47</sup>We are not considering in these simulations equilibrium effects and school budget constraints.

<sup>48</sup>Chile recently introduced a policy that provides fellowships to individuals who graduate with an education degree.

<sup>49</sup>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.

<sup>50</sup>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 increase 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.<sup>51</sup> 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 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.<sup>52</sup>

---

<sup>51</sup>They also choose to work in the small unsubsidized sector.

<sup>52</sup>Because the model is partial equilibrium in nature, the counterfactual results implicitly assume that labor demand in all sectors is infinitely elastic at equilibrium wages.

Also, if teachers care about the identity of students, then some of the counterfactual experimental results may be affected. For example, we find that an increase in the municipal wage increases the relative supply of less productive individuals to the municipal sector. If high-ability students are more likely to move to private schools as a result, and if high-ability teachers prefer high-ability students, then some high-ability teachers would move to private schools and the quality of teachers in municipal schools would be lower than our simulation predicts.

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 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 teacher labor markets operate under a voucher system. 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 developed and estimate a discrete choice dynamic programming (DCDP) model of occupational choices and we use it to evaluate a range of potential policies for improving the quality of teachers. The model builds on earlier related models of Stinebrickner (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.<sup>53</sup> 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,

---

<sup>53</sup>See Keane and Wolpin (1997) for another example of an occupational choice model where unobservable heterogeneity plays an important role.



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.

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. The existence of a private voucher sector, where teacher wages are competitively determined, attracts higher productivity individuals into the teaching profession.<sup>54</sup>

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.

---

<sup>54</sup>We do not allow for teacher effort because we do not have the necessary data. Were the data available, allowing for teacher effort would be an interesting extension. Given this non-trivial change to the model, however, we cannot speculate with confidence about how that extension would affect the counterfactual results.

## References

- [1] AUGUSTE, SEBASTIAN AND VALENZUELA, JUAN PABLO. 2003. Do students benefit from school competition? Evidence from Chile. *Mimeo*, University of Michigan.
- [2] 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.
- [3] BALLOU, DALE AND MICHAEL PODGURSKY. 1995. Recruiting Smarter Teachers. *Journal of Human Resources*, 30(2), 326-38.
- [4] BALLOU, DALE AND MICHAEL PODGURSKY. (1997): *Teacher Pay and Teacher Quality*. WE Upjohn Inst. Kalamazoo: Michigan.
- [5] BEN-PORATH, YORAM. 1967. The production of human capital and the life cycle of earnings. *The Journal of Political Economy*, 75, no. 4: 352-365.
- [6] BOHLMARK, ANDERS AND MIKAEL LINDAHL. 2008. Does school privatization improve educational achievement? Evidence from Sweden's voucher reform, IZA working paper 3691.
- [7] 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.
- [8] BRAVO, DAVID AND FLORES, BÁRBARA AND MEDRANO, PATRICIA AND SANTIAGO, DICIEMBRE DE. 2010. ¿ Se premia la habilidad en el mercado laboral docente?¿ Cuánto impacta en el desempeño de los estudiantes?. *Serie Documentos de Trabajo*.
- [9] BREWER, DOMINIC J.1996. "Career Paths and Quit Decisions: Evidence from Teaching," *Journal of Labor Economics*, 14:2(April), 313-39.
- [10] CARNOY, MARTIN. 1997. Is Privatization through Education Vouchers Really the Answer? A Comment on West. *The World Bank Research Observer*, 12, No. 1: 105-116.
- [11] CARD, DAVID, MARTIN DOOLEY AND ABIGAIL PAYNE. 2008. School Competition and Efficiency with Publicly Funded Catholic Schools. *NBER working paper* N. 14176.

- [12] CHAN, PING CHING WINNIE. 2009. School Choice, Competition and Public School Performance. Ph.D. Dissertation. University of Toronto.
- [13] CHEN, DANDAN. 2009. The Economics of Teacher Supply in Indonesia. Washington, DC: World Bank. *World Bank Policy Research Working Paper Series*, No. 4975.
- [14] 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.
- [15] CONTRERAS, DANTE. 2002. Vouchers, School Choice, and Access to Higher Education. *Yale University Economic Growth Center Discussion Paper* No. 845.
- [16] CORCORAN, SEAN P AND EVANS, WILLIAM N AND SCHWAB, ROBERT S. 2004. Changing labor market opportunities for women and the quality of teachers 1957-1992. *American Economic Review Papers and Proceedings*, 94:2 : 230-235.
- [17] CORREA, JUAN A AND PARRO, FRANCISCO AND REYES, LORETO. 2014. Self-Selection in the Market of Teachers. manuscript, Universidad Andriçoes Bello.
- [18] DOLTON, PETER J. AND WILBERT VON DER KLAAUW. 1995. Leaving Teaching in the UK: A Duration Analysis. *Economic Journal*, 105, No. 429: 431-44.
- [19] 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.
- [20] DOLTON, PETER J. 2006. Chapter 19 Teacher Supply. In *Handbook of the Economics of Education*, ed. E. Hanushek and F. Welch, Elsevier, 1079-161.
- [21] DOLTON, PETER J. 1990. The Economics of UK Teacher Supply: The Graduate's Decision. *Economic Journal*, 100(400): 91-104.
- [22] 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.

- [23] ELACQUA, GREGORY. 2006. Public, Catholic, and for-profit school enrollment practices in response to vouchers: Evidence from Chile, manuscript.
- [24] FALCH, TORBERG. 2010. The Elasticity of Labor Supply at the Establishment Level. *Journal of Labor Economics*, 28(2): 237-66.
- [25] FALCH, TORBERG. 2011. Teacher Mobility Responses to Wage Changes: Evidence from a Quasi-Natural Experiment." *American Economic Review*, 101(3), 460-65.
- [26] FERREYRA, MARIA. 2007. Estimating the Effects of Private School Vouchers in Multi-District Economies, *American Economic Review*, 97, Issue 3: 787-817.
- [27] FIGLIO, DAVID N. 2002. Can Public Schools Buy Better-Qualified Teachers? *Industrial and Labor Relations Review*, 55(4): 686-99.
- [28] FIGLIO, DAVID AND CASSANDRA M. D. HART. 2014. Competitive Effects of Means-Tested School Vouchers, *American Economic Journal: Applied Economics*, Volume 6, Number 1: 133-156.
- [29] FRANCISCO GALLEGO AND ANDRÉS HERNANDO. 2009) School Choice in Chile: Looking at the Demand Side, Documentos de Trabajo 356, Instituto de Economía. Pontificia Universidad Católica de Chile.
- [30] GIBBONS, STEPHEN, OLMO SILVA AND STEPHEN MACHIN. 2008. Choice, Competition and Pupil Achievement, *Journal of the European Economic Association*, 6, No. 4 : 912-947.
- [31] GOURIERIOUX, CHRISTIAN AND ALAIN MONFORT. 2002. *Simulation-Based Econometric Methods*, Oxford University Press.
- [32] GREENBAUM, ROBERT T. 2002. A Spatial Study of Teachers' Salaries in Pennsylvania School Districts." *Journal of Labor Research*, 23(1): 69-86.
- [33] 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.

- [34] 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>.
- [35] HANUSHEK, ERIC A. AND STEVEN G. RIVKIN. 2006. Teacher Quality, in *Handbook of the Economics of Education*, eds. E. Hanushek and F. Welch, Elsevier, 1051-78.
- [36] HERNANI-LIMARINO, WERNER. 2005. Are Teachers Well Paid in Latin America and the Caribbean? Relative Wage and Structure of Returns of Teachers. In *Incentives to Improve Teaching: Lessons from Latin America*, ed. Emiliana Vegas, Washington, D.C. World Bank: 63-102.
- [37] 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.
- [38] HECKMAN, JAMES J AND GUILHERME SEDLACEK. 1985. Heterogeneity, aggregation, and market wage functions: an empirical model of self-selection in the labor market, *The Journal of Political Economy*, Vol. 93, No. 6, 1077-1125.
- [39] HOXBY, CAROLINE. 2002. Would School Choice Change the Teaching Profession. *Journal of Human Resources*, v. 37, n. 4: 846-91.
- [40] HOXBY, CAROLINE. 2003a. Introduction. in *The Economics of School Choice*, edited by Caroline M. Hoxby, University of Chicago Press: Chicago, p. 1-22.
- [41] 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: 287-342.
- [42] 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..

- [43] HSIEH, CHANG-TAI AND MIGUEL URQUIOLA. 2006. The effects of generalized school choice on achievement and stratification: Evidence from Chile's voucher program, *Journal of Public Economics*, 90, 1477-1503.
- [44] IMAZEKI, JENNIFER. 2005. Teacher Salaries and Teacher Attrition. *Economics of Education Review*, 24(4): 431-49.
- [45] INGERSOLL, RICHARD M. 2003. The Teacher Shortage: Myth or Reality? *Educational Horizons*, 81(3): 146-52.
- [46] 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).
- [47] KEANE, MICHAEL P. AND KENNETH I. WOLPIN. 1997. The Career Decisions of Young Men. *Journal of Political Economy*, 105, 3: 473-522.
- [48] KEANE, MICHAEL, PETRA E. TODD AND KENNETH I. WOLPIN. 2010. The Structural Estimation of Behavioral Models: Discrete Choice Dynamic Programming Methods and Applications. In *Handbook of Labor Economics*, ed. David Card and Orley Ashenfelter, Volume 2, Elsevier, 332-461.
- [49] 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.
- [50] LADD, HELEN. 2002. School vouchers: a critical view. *Journal of Economic Perspectives*, 16(4): 3-24.
- [51] LARRANAGA, OSVALDO. 2004. Competencia y Participación Privada: la Experiencia Chilena en Educación. Documento de Trabajo # 207, Departamento de Economía, Universidad de Chile.
- [52] LAVY, VICTOR. 2007. Using Performance-Based Pay to Improve the Quality of Teachers. *The Future of Children*, 87-109.

- [53] 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>.
- [54] LEIGH, ANDREW 2012. Teacher Pay and Teacher Aptitude. *Economics of Education Review*, 31(3): 41-53.
- [55] LIU, H, MROZ, T. AND W. VAN DER KLAUW. 2003. "Maternal Employment, Migration and Child Development," working paper, University of North Carolina, Chapel Hill.
- [56] 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.
- [57] 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.
- [58] 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.
- [59] MIZALA, ALEJANDRA AND PILAR ROMAGUERA. 2005. Teachers' Salary Structure and Incentives in Chile. In *Incentives to Improve Teaching: Lessons from Latin America*, ed. Emiliana Vegas. Washington, D.C.: World Bank: 103-50.
- [60] MONT, D. AND D.I. REES. 1996. The Influence of Classroom Characteristics on High School Teacher Turnover." *Economic Inquiry*, 34(1): 152-67.
- [61] 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.
- [62] 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.

- [63] NEAL, DEREK. 2002. How Vouchers Would Change the Market for Education. *Journal of Economic Perspectives*, 16:4: 25-44.
- [64] NEWEY, WHITNEY AND DANIEL MCFADDEN. 1994. Large sample estimation and hypothesis testing," in *Handbook of Econometrics*, Volume 4: 2111-2245.
- [65] ONDRICH, JAN, EMILY PAS AND JOHN YINGER. 2008. The Determinants of Teacher Attrition in Upstate New York. *Public Finance Review*, 36(1):112-44.
- [66] 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.
- [67] 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.
- [68] REES, D.I. 1991. Grievance Procedure Strength and Teacher Quits." *Industrial and Labor Relations Review*, 45(1): 31.
- [69] 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.
- [70] RIVKIN, STEVEN G. AND ERIC A. HANUSHEK AND JOHN F. KAIN. 2005. Teachers, schools, and academic achievement. *Econometrica*, 73:2: 417-458.
- [71] ROUSE, CECILIA. 1998. Private School Vouchers and Student Achievement: The Effect of the Milwaukee Parental Choice Program," *Quarterly Journal of Economics*, 113:553-602.
- [72] ROY, R.D. 1951. Some Thoughts on the Distribution of Earnings." *Oxford economic papers*. 3:2: 135-146.
- [73] SANDSTROM, F. MIKAEL AND FREDRIK BERGSTROM. 2005. School vouchers in practice: competition will not hurt you. *Journal of Public Economics* 89, 351-380.
- [74] SAPELLI, C. AND B. VIAL. 2002. The Performance of Private and Public Schools in the Chilean Voucher System. *Cuadernos de economia*, 39, 118: 423-454.



- [75] 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.
- [76] 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.
- [77] STINEBRICKNER, TODD R. 1998. An Empirical Investigation of Teacher Attrition." *Economics of Education Review*, 17(2), 127-36.
- [78] STINEBRICKNER, TODD R. 2001a. Compensation Policies and Teacher Decisions," *International Economic Review*, 42:3.
- [79] STINEBRICKNER, TODD R. 2001b. A Dynamic Model of Teacher Labor Supply," *Journal of Labor Economics*, 19(1): 196-230.
- [80] THEOBALD, NEIL 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.
- [81] 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.
- [82] TINCANI, MICHELA. 2014. School Vouchers and the Joint Sorting of Students and Teachers. HCEO Working Paper No. 2014-012.
- [83] TOKMAN, ANDREA RAMOS. 2002. Is Private Education Better? Evidence from Chile. Working paper. Central Bank of Chile 147. Central Bank of Chile.
- [84] VERHOOGEN, ERIC AND MIGUEL URQUIOLA 2009. Class-Size Caps, Sorting, and the Regression-Discontinuity Design. *American Economic Review*, Vol. 99, No. 1: 179-215.
- [85] VEGAS, EMILIANA. 2002. School Choice, Student Performance, and Teacher and School Characteristics: The Chilean Case," World Bank Report.

- [86] WEST, MARTIN AND LUDGER WOESSMAN. 2010. Every Catholic Child in a Catholic School?: Historical Resistance to State Schooling, Contemporary Private Competition and Student Achievement across Countries. *Economic Journal*, 12-(546): 229-255.
- [87] WEST, MARTIN R. AND LUDGER WOESSMANN. 2010. Every Catholic Child in a Catholic School: Historical Resistance to State Schooling, Contemporary Private Competition and Student Achievement Across Countries. *Economic Journal*, 120(546): 229-255.
- [88] WISWALL, MATTHEW. 2007. Licensing and Occupational Sorting in the Market for Teachers, manuscript, New York University, Department of Economics.
- [89] WOLTER, STEFAN C. AND STEFAN DENZLER. 2004. Wage Elasticity of the Teacher Supply in Switzerland. *Brussels Economic Review*, 47(3-4): 387-407.
- [90] 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  $D_{i,Z'_{ia},\bar{A}'} = 1$ , which may overlap with the set of observations for which  $D_{i,Z_{ia},\bar{A}} = 1$ .

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

To simplify the notation, we suppress the dependence of  $\hat{y}$  on  $\gamma$ . 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:

$$\hat{V}_N = \left(\frac{1}{N}\right)^2 \times \sum_{i=1}^{N_I} \sum_{a=a_0}^{a'} \sum_{l=a_0}^{a'} \begin{bmatrix} (y_{ia}^1 - \hat{y}_{ia}^1)(y_{il}^1 - \hat{y}_{il}^1) D_{i,Z_{ia},\bar{A}} D_{i,Z_{il},\bar{A}} w_i^2 & (y_{ia}^1 - \hat{y}_{ia}^1)(y_{il}^2 - \hat{y}_{il}^2) D_{i,Z_{ia},\bar{A}} D_{i,Z'_{il},\bar{A}'} w_i^2 \\ (y_{ia}^2 - \hat{y}_{ia}^2)(y_{il}^1 - \hat{y}_{il}^1) D_{i,Z_{ia},\bar{A}} D_{i,Z'_{il},\bar{A}'} w_i^2 & (y_{ia}^2 - \hat{y}_{ia}^2)(y_{il}^2 - \hat{y}_{il}^2) D_{i,Z'_{ia},\bar{A}'} D_{i,Z'_{il},\bar{A}'} w_i^2 \end{bmatrix}$$

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  $\Gamma$  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  $\gamma$ .) The dimensionality of  $\Gamma$  is  $K \times m$ . For example, for two moments, the  $\Gamma'$  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  $\Gamma$  matrix are estimated by numerical derivatives. Let  $\gamma_i$  denote the  $i$ th element of  $\gamma$  and let  $\Delta_i$  denote the same size vector  $\Delta_i$  that is zero everywhere except in the  $i$ th element, which is a small positive number. Then the derivative of moment  $m$  with respect to  $\gamma_i$  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:

- *agecat1* separates age into the following three categories: [23, 34], [35, 44], [45, 54]

- *agecat1males* separates the age of males into the following categories, and it is used only for the fertility moments: [23, 44], [45, 54]
- *agecat2* separates age into the following four categories: [23, 29], [30, 34], [35, 44], [45, 54]
- *texpcat* separates teaching experience into the following categories: [0, 4], [5, 9], [10, 14], [15, 19]
- *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<sup>55</sup>
- (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)
- (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)

---

<sup>55</sup>We don't match fractions in 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:

- *agecat1* separates age into the following three categories: [22, 34], [35, 44], [45, 54]
- *agecat2* separates age into the following four categories: [22, 29], [30, 34], [35, 44], [45, 54]
- *ntexpcat* separates non-teaching experience into the following categories: [0, 4], [5, 9], [10, 14], [15, 19]
- *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<sup>56</sup>

*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:

---

<sup>56</sup>We match only persistence because transition to the other sector is defined residually.

- (ix) the fraction of males who get certified
- (x) the fraction of females who get certified

using the EPS data.<sup>57</sup>

## 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.

---

<sup>57</sup>The fraction getting certified is not observed in the ELD dataset, which only contains information on teachers.



## 10 Tables

Table 1: Parameter Estimates (Standard Errors in Parentheses)

Utility of Obtaining an Education Degree		Payoff: Non-Teaching Sector	
Type 1 - $\lambda_{01}$	-2.610E+08 (2.20E+05)	Type 1 - $\alpha_{01}^{NT}$	14.95 (0.017)
Type 2 - $\lambda_{02}$	-8.011E+07 (7.41E+05)	Type 2 - $\alpha_{02}^{NT}$	15.93 (0.016)
Type 3 - $\lambda_{03}$	-9.821E+07 (1.19E+05)	Type 3 - $\alpha_{03}^{NT}$	15.51 (0.017)
Female - $\lambda_1$	6.390+E07 (6.78E+04)	Teaching Experience - $\alpha_1^{NT}$	0.028 (1.46E-05)
Age at graduation/cert. - $\lambda_2$	1.280E+06 (198.40)	Non-Teaching Experience - $\alpha_2^{NT}$	0.055 (6.63E-05)
Std. dev. - $\sigma_\eta$	18.56 (0.021)	Non-Teaching Exp Squared - $\alpha_3^{NT}$	-0.00243 (3.49E-06)
		Has an education degree - $\alpha_4^{NT}$	-0.176 (3.94E-04)
		Female - $\alpha_5^{NT}$	-0.286 (3.34E-04)
Payoff: Municipal Schools		Payoff: Home Sector	
Constant term - $\alpha_0^M$	15.00 (0.025)	Type 1 - $\beta_{01}^H$	1.301E+06 (1909.97)
Experience - $\alpha_1^M$	0.025 (4.23E-05)	Type 2 - $\beta_{02}^H$	-1.465E+08 (38343.19)

*continued on next page*

Experience squared - $\alpha_2^M$	-0.0015 (1.70E-07)	Type 3 - $\beta_{03}^H$	3.947E+05 (1694.61)
Nonpec., type 1 - $\beta^{M01}$	-3.975E+06 (1145.86)	Number of children $\times$ age < 51 - $\beta_1^H$	3.120E+05 (135.43)
Nonpec., type 2 - $\beta^{M02}$	4.973E+06 (187.09)	Number of children $\times$ female $\times$ age < 51 - $\beta_1^H$	1.120E+05 (107.37)
Nonpec., type 3 - $\beta^{M03}$	1.235E+06 (715.21)		
Payoff: Voucher Schools		Transition Costs	
Type 1 - $\alpha_{01}^V$	14.88 (0.005)	Switching sectors, not at home last period - $c^s$	-2.524E+08 (432527.46)
Type 2 - $\alpha_{02}^V$	17.03 (0.004)	Laid off from teaching last period - $c^l$	-2.394E+07 (12423.37)
Type 3 - $\alpha_{03}^V$	15.06 (0.020)	Home last period - $c^w$	-7.598E+06 (9538.76)
Experience - $\alpha_1^V$	0.054 (1.07E-04)	Log of the Std. dev. of Payoffs	
Experience squared - $\alpha_2^V$	-0.00144 (1.84E-06)	Municipal sector - $\sigma^M$	-0.347 (5.01E-04)
Female - $\alpha_3^V$	-0.105 (5.54E-05)	Voucher sector - $\sigma^V$	-0.270 (2.87E-04)
Nonpec., type 1 - $\beta_{01}^V$	-4.891E+07 (866.01)	Unsubsidized sector - $\sigma^U$	-0.765 (1.43E-03)
Nonpec., type 2 - $\beta_{02}^V$	-2.688E+07	Non-teaching sector - $\sigma^{NT}$	-0.119

*continued on next page*

	(543.18)		(1.70E-04)
Nonpec., type 3 - $\beta_{03}^V$	8.255E+05	Home sector - $\sigma^H$	1.34E+01
	(913.04)		(0.016)
Payoff: Unsubsidized Schools		Fertility Process	
Type 1 - $\alpha_{01}^U$	14.90	Type 1 - $\gamma_{01}^f$	-9.25
	(0.004)		(0.039)
Type 2 - $\alpha_{02}^U$	16.70	Type 2 - $\gamma_{02}^f$	-9.49
	(0.013)		(0.031)
Type 3 - $\alpha_{03}^U$	15.16	Type 3 - $\gamma_{03}^f$	-0.468
	(0.016)		(7.11E-04)
Experience - $\alpha_1^U$	0.075	Age - $\gamma_1^f$	0.049
	(9.93E-05)		(8.08E-05)
Experience squared - $\alpha_2^U$	-0.0020	Age squared - $\gamma_2^f$	-0.003
	(2.24E-06)		(4.46E-06)
Female - $\alpha_3^U$	-0.078	Age×female - $\gamma_3^f$	-0.012
	(6.20E-05)		(7.22E-06)
Nonpec., type 1 - $\beta_{01}^U$	-3.081E+07	Number of children - $\gamma_4^f$	0.233
	(999.64)		(2.04E-04)
Nonpec., type 2 - $\beta_{02}^U$	-3.139E+07	Birth last period - $\gamma_5^f$	-1.312
	(28881.44)		(0.002)
Nonpec., type 3 - $\beta_{03}^U$	-2.804E+05		
	(387.88)		
Dismissal Process			
<i>continued on next page</i>			

---

Constant - $\gamma_0^{IT}$	-2.904		
	(0.005)		
Teaching experience - $\gamma_1^{IT}$	-0.148		
	(1.80E-04)		
Constant - $\gamma_0^{INT}$	-2.197		
	(0.003)		
Non-teaching experience - $\gamma_1^{INT}$	-0.082		
	(9.11E-05)		
Probability of Type 2		Probability of Type 3	
Constant - $\omega_{20}$	-2.465	Constant - $\omega_{30}$	-0.243
	(0.010)		(0.022)
Female - $\omega_{21}$	-1.250	Female - $\omega_{31}$	0.035
	(0.006)		(0.018)
Teaching experience - $\omega_{22}$	-1.564	Teaching experience - $\omega_{32}$	0.105
	(7.60E-04)		(5.47E-05)
Teaching exp squared - $\omega_{23}$	0.135	Teaching exp squared - $\omega_{33}$	0.083
	(0.002)		(0.017)
Number of children - $\omega_{24}$	0.793	Number of children - $\omega_{34}$	2.739
	(0.012)		(0.013)
Non-teaching sector	-0.711	Non-teaching sector	-0.566
last period - $\omega_{25}$	(0.119)	last period - $\omega_{35}$	(0.003)
Laid off from teaching	5.840	Laid off from teaching	-9.350
last period - $\omega_{26}$	(0.037)	last period - $\omega_{36}$	(0.010)
Age at	-0.0056	Age at	-0.080

---

*continued on next page*

---

graduation/cert. - $\omega_{27}$	(0.001)	graduation/cert. - $\omega_{37}$	(8.92E-04)
Birth last period - $\omega_{28}$	1.630	Birth last period - $\omega_{38}$	-2.500
	(0.004)		(0.013)
In ELD sample - $\omega_{ELD}$	0.315	In ELD sample - $\omega_{ELD}$	5.803
	(0.094)		(0.001)

---

Table 2: Model Fit

	Actual	Model
Proportion With Education Degree		
Female	0.178	0.177
Male	0.061	0.062
Proportion of teachers Employed in:		
Municipal Schools		
Female	0.338	0.348
Male	0.296	0.318
Voucher Schools		
Female	0.483	0.506
Male	0.482	0.512
Unsubsidized Schools		
Female	0.118	0.124
Male	0.140	0.150
Non-Teaching Jobs		
Female	0.022	0.014
Male	0.041	0.013
Proportion of Non-Teachers Employed		
Female	0.757	0.785
Male	0.852	0.885
Mean Accepted Wages (in 1,000 pesos): Teachers		
Municipal Schools		
Female	4989	4858
Male	5352	4652
Voucher Schools		
Female	5586	6459
Male	6320	7715
Unsubsidized Schools		
Female	6412	5287
Male	7208	6108
Mean Accepted Wages (in 1,000 pesos): Non-Teachers		
Female	5809	5211
Male	8264	7681

Table 3: Type Proportions

	Females			Males		
	Type 1	Type 2	Type 3	Type 1	Type 2	Type 3
Population						
Proportion	0.730	0.018	0.253	0.721	0.059	0.221
Proportion Given an						
Education Degree	0.184	0.090	0.726	0.060	0.450	0.490
Proportion Given a						
Non-Education Degree	0.847	0.002	0.151	0.764	0.033	0.203

Table 4: Counterfactual Policies

	Baseline			Bonus to Education Degree:			20% Increase in Municipal Wage			Municipal Schools			Eliminate Voucher Schools		
	All.	Fem.	Male	All.	Fem.	Male	All.	Fem.	Male	Function			All.	Fem.	Male
										School Wage	School Wage	School Wage			
Prop. with Education Degree	0.121	0.177	0.062	0.128	0.187	0.067	0.136	0.199	0.070	0.137	0.178	0.095	0.104	0.166	0.038
Proportion Given Education Degree of															
Type 1	0.153	0.184	0.060	0.161	0.193	0.067	0.179	0.213	0.078	0.131	0.178	0.038	0.186	0.204	0.103
Type 2	0.180	0.090	0.450	0.176	0.086	0.440	0.160	0.080	0.397	0.273	0.099	0.615	0.065	0.049	0.140
Type 3	0.667	0.726	0.490	0.663	0.721	0.494	0.661	0.707	0.524	0.596	0.723	0.347	0.759	0.747	0.757
Proportion Working in Municipal Schools of															
Type 1	0.014	0.013	0.049	0.015	0.013	0.047	0.215	0.226	0.147	0.001	0.000	0.001	0.021	0.019	0.030
Type 2	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000	0.530	0.253	0.794	0.117	0.078	0.312
Type 3	0.986	0.987	0.951	0.985	0.987	0.953	0.783	0.772	0.853	0.469	0.747	0.205	0.862	0.903	0.658
Proportion Working in Voucher Schools of															
Type 1	0.001	0.002	0.000	0.001	0.002	0.000	0.000	0.001	0.000	0.013	0.015	0.001	0.000	0.000	0.000
Type 2	0.572	0.449	0.688	0.563	0.438	0.677	0.976	0.983	0.971	0.006	0.001	0.031	0.000	0.000	0.000
Type 3	0.427	0.549	0.312	0.436	0.560	0.323	0.024	0.016	0.029	0.981	0.984	0.968	0.000	0.000	0.000
Proportion Working in Unsubsidized Schools of															
Type 1	0.037	0.050	0.003	0.036	0.050	0.003	0.240	0.278	0.000	0.125	0.135	0.021	0.018	0.047	0.001
Type 2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Type 3	0.963	0.950	0.997	0.964	0.950	0.997	0.760	0.772	1.00	0.875	0.865	0.979	0.982	0.953	0.999