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Effects of school reform on education and labor market performance: Evidence from Chile's universal voucher system

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This paper studies the effects of school reform in Chile, which adopted a nationwide school voucher program along with school decentralization reforms in 1981. Since then, Chile has had a relatively unregulated, competitive market in primary and secondary education. It therefore provides a unique setting in which to study how these reforms affected school attainment and labor market outcomes. This paper develops and estimates a dynamic model of school attendance and work decisions using panel data from the 2002 and 2004 waves of the Encuesta de Protección Social survey. Some individuals in the sample completed their schooling before the voucher reforms were introduced, while others had the option of using the vouchers over part or all of their schooling careers. The impacts of the voucher reform are identified from differences in the schooling and work choices made and earnings returns received by similar aged individuals who were differentially exposed to the voucher system. Simulations based on the estimated model show that the voucher reform significantly increased the demand for private subsidized

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schools and decreased the demand for both public and nonsubsidized private schools. It increased high school (grades 9–12) graduation rates by 3.6 percentage points and the percentage completing at least two years of college by 2.6 percentage points. Individuals from poor and non-poor backgrounds on average experienced similar schooling attainment gains. The reform also increased lifetime utility and modestly reduced earnings inequality.

Keywords. School vouchers, dynamic schooling model, human capital production.

JEL classification. I21, I22, I28, J22, J24.

1. Introduction

School vouchers were proposed by Friedman (1955, 1962) as a way to improve school quality. Friedman supported a role for government in school funding, but argued that schooling might be more efficiently provided in the private sector. At first, his voucher proposal was considered a radical idea, but school vouchers have since garnered support among policy-makers. Recent advocates of voucher programs point to their value in fostering school competition, which is thought to generate quality improvements in both public and private school systems, and to their potential value in promoting equality of educational opportunity (Brighouse (2000), Rouse (1998), Hoxby (2001, 2003a)). However, critics caution that voucher programs deplete already poorly funded public school systems of revenue, of their best students and teachers, and may increase inequality (e.g., Carnoy (1997), Ladd (2002)).

School voucher programs have been implemented in some U.S. cities, including Milwaukee, Dayton, New York City, the District of Columbia, Cleveland, and Denver and in the state of Florida. Most of the programs are available only to children from low income families and/or from poor performing schools.[1] There is mixed evidence on their effectiveness in improving child test scores (e.g., Krueger and Zhu (2004), Yau (2004), Peterson, Howell, and Greene (1999)). The small scale of most programs and their selective targeting make it difficult to draw inferences about the likely effects of vouchers on a broad scale. There are no empirical studies for the United States or other countries of the potential long-term effects of voucher programs on schooling attainment, earnings, and employment outcomes of voucher recipients.

This paper studies the effects of a school voucher reform in Chile that was adopted nationwide in 1981. At that time, Chilean economic and social policy was strongly influenced by the Chicago school of economics and its decentralization policies (Valdes (1995)). Under Augusto Pinochet's military government, the control of public schools was transferred to municipal authorities and the school funding system was converted to a per capita voucher system, with public and private schools receiving the same voucher amounts. Prior to these reforms, Chile had a long tradition of providing some public support for private (mainly Catholic) schools, but the voucher system greatly increased the level of support going to private schools. Two other significant changes accompanying the reforms were that teacher union contracts were revoked, giving public

[1]The Cleveland program is an exception.

schools greater flexibility in hiring and firing teachers, and national curriculum standards were relaxed, giving schools more leeway in setting their curriculum.[2] There was no direct attempt to improve quality of instruction in schools, because it was thought that increased competition among schools would stimulate improvements. Consistent with this view, total public spending on education fell in the decade following the reform. According to Parry (1997b), education expenditure in 1972 was almost 6% of gross domestic product, but fell after the Pinochet government took power to a low of 2.5% in 1990. The real value of the per-student subsidy declined by 28% over the decade of the 1980s. Carnoy (1996) noted that most of the decrease in public education subsidies came at the secondary and university levels, where per-student public spending declined drastically.

The design of Chile's voucher system is in many ways similar to Friedman's original proposal. Vouchers are publicly funded with voucher funds following the child to selected schools. Government and private schooling sectors coexist with free entry into the private sector and some government monitoring of the quality of all schools.[3] Since 1981, Chile has been a virtual laboratory for a relatively unregulated, decentralized, competitive market in primary and secondary education. It therefore provides a unique setting in which to analyze how voucher and decentralization reforms on a nationwide scale affected school choice and longer-term educational attainment and labor market outcomes. We can also examine how the reforms affected inequality by changing the opportunities for children from poorer families to attend private schools and/or by changing the types of schools attended by children from wealthier families.

Education in Chile is provided by three broad types of schools: municipal schools, private subsidized schools, and private nonsubsidized (fee-paying) schools. Private subsidized schools and municipal schools were financed primarily through the per capita government voucher until 1994, when a change in the law allowed private schools and municipal high schools to charge a small add-on tuition.[4] As further described below, most of our analysis sample attended school prior to this change during the pure voucher regime. Private nonsubsidized schools, which include both religious (mainly Catholic) and lay schools, are financed from private tuition. Private subsidized schools can be for-profit or not for profit, while private nonsubsidized schools are usually for-profit.[5] Parents are free to choose among municipal and both types of private schools. An important difference between public and private schools' admissions policies is that private schools can be selective, whereas public schools can only be selective if there is excess demand. In all types of schools, students are required to take standardized tests in the fourth, eighth, and tenth grades, called the SIMCE tests. The school's average test results are published annually, and parents can compare the performance of their school to that of other locally available schools.

[2]Carnoy (1997).

[3]For example, schools are required to have licensed teachers. They also do not receive additional voucher payments for class sizes that exceed 45 students (McEwan and Urquiola (2005)).

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

[5]About three-quarters of private voucher schools are for-profit (Elacqua (2006)).

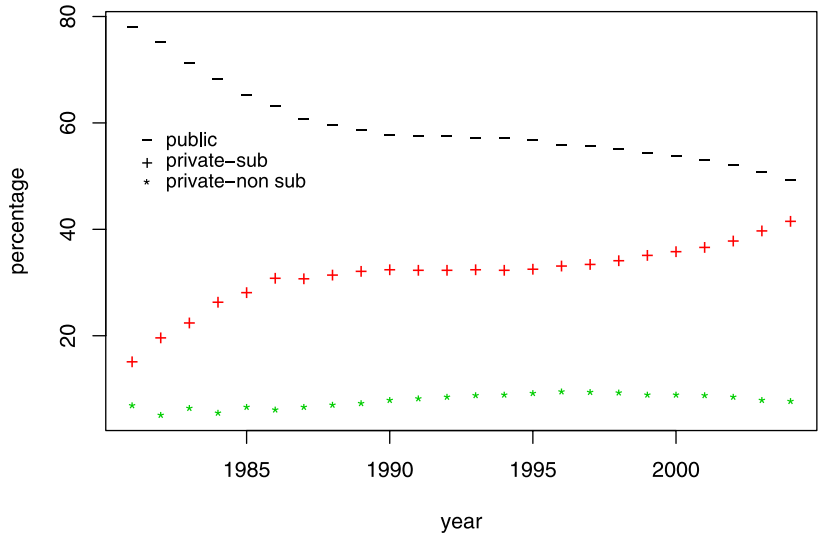

FIGURE 1. Percentage of students attending different types of schools by year.

Figure 1 shows the percentage of students attending different kinds of schools from 1981 to 2004.[6] In the first 5 years after the voucher reform was introduced, the percentage enrolled in private subsidized schools increased rapidly, from 15% to over 30%, with a corresponding decline in public school enrollment. Subsequently, the share of private subsidized schools continued to increase at a more gradual pace and the corresponding market share of public schools decreased. The market share of private nonsubsidized schools varied only a little over time, ranging from 5.5 to 9.5%.

There are a number of previous studies of the effects of voucher programs in Chile (e.g., Mizala and Romaguera (2000), Sapelli and Vial (2002), Contreras (2001), Hsieh and Urquiola (2003, 2006), McEwan (2001), McEwan, Urquiola, and Vegas (2008)) that analyze the relationship between standardized test scores and attendance at public and private schools using data collected at the schools. Some studies find little difference in test score performance between municipal and private subsidized schools after controlling for family background. As Mizala and Romaguera (2000), Bravo (1999), and Larrañaga (2004) noted, however, the test score data were gathered many years after the voucher reforms, and the finding of no significant difference could be consistent with the voucher reform having improved performance in both the private and public sectors. Other studies, such as Bravo, Contreras, and Sanhueza (1999) and Sapelli and Vial (2002) found evidence of better performance in private schools. With test score data collected in school, one encounters multiple selection problems, namely, that the children/youth attending each type of school are self-selected and that test scores are only observed for those attending school. Section 2 discusses how the literature addresses concerns about selectivity.

Rather than study the determinants of test scores, this paper uses household survey data to study the longer-term effects of the school voucher reforms on schooling

[6]The figure is based on data from the Ministry of Education.

attainment, employment, and earnings.[7] Our analysis samples are drawn from the longitudinal survey in Chile called the Encuesta de Protección Social (EPS), which elicited information from respondents on the primary and secondary schools attended, and on schooling and labor market outcomes.[8] We use data collected in the 2002 and 2004 waves, which contain rich demographic, labor market, and pension-related information for a random sample of working age Chileans. Most relevant for our analysis is the information on the schools attended, family background, earnings, and 25 years of retrospective work history.

One challenge in estimating the effects of the school voucher reform on education and employment is that the voucher reform was introduced throughout Chile in 1981 with no explicit variation in the timing of availability. However, Chileans were at different points in their schooling careers when the reform was introduced and were therefore differentially exposed to it, depending on their age. Our analysis sample includes individuals who attended school prior to the reform, who were in the midst of their schooling careers at the time of the reform, and who attended solely in the post-voucher regime. The long time frame covered by the data and our modeling approach allows us to exploit variation in exposure to evaluate the effects of the reforms on longer-term educational and labor market outcomes. This question has never been previously examined in the literature.

To this end, we develop and estimate a dynamic behavioral model of schooling and labor force participation decisions that incorporates multiple channels through which voucher reforms can operate. The model builds on a well developed labor literature analyzing labor market outcomes in the presence of self-selection into educational and/or occupational sectors. The seminal paper is that of Roy (1951), which explores the implications of occupational self-selection for earnings distributions within a static earnings optimization model.[9] Willis and Rosen (1979) extended the Roy model to an educational choice setting where individuals choose whether to attend college, basing their decisions on expected lifetime earnings, on financing capacities that differ by family background, and on nonpecuniary benefits of education. The model we develop also builds on Heckman and Sedlacek's (1985) study of earnings distributions in which individuals self-select into different economic sectors with the option of remaining out of the labor force. In our context, individuals select among different schooling sectors (municipal, subsidized private, and nonsubsidized private), and make decisions about how long to attend school and whether and when to participate in the labor force. Our model explicitly controls for both observed and unobserved sources of heterogeneity that may affect selection into different types of schools as well as earnings offers and preference parameters.

[7]As emphasized in recent work by Heckman, Stixrud, and Urzua (2006) and Carneiro, Cunha, and Heckman (2003), cognitive ability as measured on standardized tests is only one of several factors that determine labor market success.

[8]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. The data can be obtained through the website www.proteccionsocial.cl. For descriptive analysis of the data, see Bravo, Behrman, Mitchell, and Todd (2006).

[9]Heckman and Honore (1990) exposited the mathematical foundations for the Roy model.

Along the lines of Ben-Porath (1967), Keane and Wolpin (1997), and Heckman and Navarro (2005), our conceptualization of the schooling decision and of the earnings offer equation assumes that individuals forgo earnings opportunities during periods of schooling investment, that they are motivated to undertake investments by anticipated future returns, and that earnings offers represent a price paid to the human capital embodied in an individual.[10] In the tradition of Behrman and Birdsall (1983) and Card and Krueger (1992), we allow the returns to schooling to depend on the types of primary and secondary school attended and on whether attendance took place in the pre- or post-voucher regime. Our specification allows the voucher reforms to have potentially altered the quality of schooling provided in both the private and public sectors.

The dynamic discrete choice model that we estimate allows components of future earnings and of the payoff to different types of schooling to be unknown at the time of making schooling and labor market decisions. It also incorporates permanent unobservable heterogeneity in the form of discrete types that are assumed to be known to individuals but unknown to the econometrician (Heckman and Singer (1984)). The type distribution is allowed to vary by 10-year birth cohorts and by family background. Identification of the effects of the voucher reform comes from differences in the schooling and work choices made and earnings returns received by individuals within the same 10-year birth cohort who were differentially exposed to the reform. Within the model, labor market experience accumulates endogenously as a function of past labor supply choices. The model is estimated on males, mainly to avoid consideration of fertility choices, but also because men in Chile have much stronger labor force attachment than women.

We use the estimated model to assess how the school voucher reform influenced sorting among different types of schools, educational attainment, earnings, and labor market participation. By simulating decisions over the life cycle with and without the reform, we directly evaluate the cumulative effects of the reform as it operates through both schooling and labor market channels. Our parameter estimates indicate that the cost of attending primary and secondary schools declined substantially after the reform, falling roughly by half, which is consistent with the dramatic post-reform expansion in the availability of schools.[11] Additionally, the annual earnings return to attending municipal and private subsidized primary schools increased by roughly 0.5 percentage points after the reform. At the secondary school level, however, we estimate that the schooling return declined by about 1 percentage point in the post-voucher period relative to pre-voucher levels. The decline is likely related to the decrease in per-pupil expenditure in the decade following the voucher reform that was especially significant at the secondary level as well as to the entry of newer private secondary schools, which were thought to be, on average, of lower quality than the earlier established schools (see Carnoy (1996) and Parry (1997a, 1997b)).

We study the net effects of the voucher reform by simulating the behavior of individuals with and without the reform, taking into account the multiple channels through

[10] See Heckman, Layne-Farrar, and Todd (1996) for further discussion of the human capital pricing interpretation of the earnings equation.

[11] See Parry (1997a, 1997b) for a discussion of the expansion of the private schooling sector.

which the reforms potentially operated. Our model simulations indicate that, on the whole, the combined effects of the elimination of private school tuition, the decline in the costs of attending schools, and the increase in the returns to primary schooling resulted in a dramatic increase in attendance at private subsidized schools relative to other types of schools and increased schooling attainment for voucher recipients. On net, the voucher reforms increased primary school graduation rates by 0.6 percentage points, high school graduation rates by 3.6 percentage points, college attendance rates by 3.1 percentage points, and the percent completing at least 4 years of college by 1.8 percentage points for individuals exposed to the reform during their entire schooling career. In addition, the reform reduced labor force participation at ages 16–25 by about 2 percentage points, off a baseline of 58.3%, mainly because longer school attendance delays labor force entry. Perhaps surprisingly, we find that the voucher reforms did not increase overall mean earnings, because the earnings premium from having more education is partly offset by the post-reform decrease in secondary schooling returns. However, the reforms modestly reduced earnings inequality and substantially increased the present discounted value of lifetime utility.

The paper develops as follows. Section 2 discusses the related literature. Section 3 describes the model and Section 4 describes the estimation approach. Section 5 presents the empirical results and Section 6 concludes.

2. Background and related literature

Although there has been much speculation and debate about the likely short-term and long-term effects of large-scale school voucher programs in the United States on both students and teachers, (e.g., Neal (2002), Hoxby (2001, 2003a, 2003b)), the empirical evidence is still scarce. Much of what we know empirically comes from small-scale studies that examined the short-term effects of privately funded voucher programs on student test scores (e.g., Rouse (1998), Krueger and Zhu (2004), Yau (2004)). For example, Howell and Peterson (2002) and Peterson, Howell, Wolf, and Campbell (2003) described the results of randomized evaluations of voucher programs in Dayton, OH, New York City, and Washington, D.C., which showed that African-American children experienced statistically significant test score gains from vouchers. There remains some controversy regarding the findings, because of relatively high attrition rates in the experiment. A recent paper by Ferreyra (2007) develops and estimates a general equilibrium model of residential sorting and school choice using data from Chicago. The model is used to simulate the effects of a hypothetical large-scale universal voucher program and of a nonsectarian voucher program, both of which she finds would increase private school enrollment.

A related U.S. literature studies the effects of attending private schools or Catholic schools on student test scores and graduation rates (e.g., Neal (1997), Grogger and Neal (2000), Evans and Schwab (1995), Altonji, Elder, and Taber (2005)). That literature typically finds statistically significant positive effects of attending private schools, primarily for urban, African-American and Hispanic children/youth. Voucher programs facilitate attendance at private schools, so this evidence could be viewed as supportive of vouchers for urban, minority youth.

There have been several previous studies of the Chilean voucher program's effects on student test scores. The test score data were not systematically gathered until after the voucher reforms were initiated and are therefore not informative about school performance in the pre-reform period. The studies are informative, though, on whether private school attendance in the post-reform era is associated with higher test scores and, to some extent, address the concern that the voucher program increased sorting and benefitted high ability students at the expense of low ability students, which is predicted by some theoretical models (see, e.g., Epple and Romano (1998)).

In analyzing test score differences between public and private schools, one encounters multiple selection problems, namely that the types of children attending each school are self-selected and, for older children, that test scores are usually only available for children attending school. Using fourth grade school level average achievement test scores, Mizala and Romaguera (2000) and Bravo, Contreras, and Sanhueza (1999) found that the gap in test score performance between municipal and subsidized private schools is small after controlling for geographic and socioeconomic characteristics. McEwan and Carnoy (2000) similarly examined the relationship between type of school attended and student achievement of fourth graders. They found that nonreligious voucher schools are no more effective than public schools in producing achievement, but that Catholic voucher schools are more effective.

A few studies explicitly control for school type selectivity using frameworks that allow for selection on unobservables. For example, Sapelli and Vial (2002) analyzed public–private test score differences within a static Roy model framework and found test score gains for second graders associated with attendance at private subsidized schools, which were largest for children attending those types of schools.[12] McEwan (2001) examined the effects of attendance at a public or private voucher school on eighth grade test scores using a control function approach to account for school selectivity. He found no significant achievement differences between public and nonreligious voucher schools, but a small test score advantage for Catholic voucher schools.

Auguste and Valenzuela (2003) and Gallego (2002) analyzed the relationship between test scores and school competition, and found that competition tends to increase test scores. However, Hsieh and Urquiola (2006) found that community average standardized test scores did not increase faster in communities where private sector enrollment expanded more, interpreted as a measure of competition.[13]

Parry (1997a, 1997b) provided a good description of many features of the Chilean voucher system and documented the dramatic expansion in the supply of private schooling that followed the introduction of the voucher reforms. First, there is evidence

[12]Sapelli and Vial (2002) also found that the relative performance of private and municipal schools depends on whether municipal schools receive additional government subsidies. In areas where the municipal schools do not receive extra subsidies and expenditure on students is comparable to that in private subsidized schools, there is a significant test score gain from attending private subsidized schools.

[13]Rather, they found that average repetition and grade-for-age worsened in such areas relative to other communities. A potential limitation of the analysis is that it examines differences in test scores over time, though the tests were not comparable over time prior to 1998, when test equating was introduced. Also, the study analyzes school test scores for children age 10–15, and children who dropped out are not included in the testing.

that some high quality private schools responded to the voucher program by expanding their capacity and enrollment, and opening new schools. There was also substantial new entry into the private school market.[14] The newer subsidized private schools tended to be for-profit as opposed to religious schools, to open in higher population density areas, and to attract children from somewhat lower socioeconomic backgrounds than had attended private schools before the reform (Parry (1997a, 1997b), Hsieh and Urquiola (2006)).

Although most studies of voucher programs in Latin America focus on Chile, a small literature studies related programs in other Latin American countries. For example, Angrist, Bettinger, Bloom, King, and Kremer (2002) evaluated the impact in selected Colombian cities of the Programa de Ampliación de Cobertura de la Educación Secundaria (PACES) voucher program. The vouchers were introduced in 1991, covered about one-half the cost of private secondary schools, and were renewable with satisfactory academic performance. Evaluation of PACES was facilitated by the fact that vouchers were initially awarded by lottery in some municipalities that had excess demand for them. Angrist et al. (2002) found significant positive impacts on grade progression rates, on educational attainment after 3 years, and on standardized test scores.

This paper analyzes the effects of the Chilean school voucher and decentralization reforms on educational attainment, earnings, and labor force behavior. We first estimate a dynamic behavioral model of decisions about school attendance and labor force participation, and then use the model to simulate behavior with and without the voucher reforms. As described in the Introduction, our modeling approach is motivated by two important strands of the labor economics literature: the literature on dynamic sector selection and the literature on human capital pricing equations. Our framework imbeds a human capital pricing equation within a dynamic education and labor force selection model.

3. Model

We next describe the dynamic behavioral model that we estimate. The model assumes that the decision process starts at age 6, when parents choose the type of primary schooling their child will attend to maximize the child's lifetime utility.[15] The three choices are public municipal (M), private subsidized (S), or private unsubsidized (NS). We assume that once the choice of primary school type is made, there is no switching to a different type, because the data only record one type of primary and secondary school attended. All children are assumed to attend school through the second grade, which is the case in the data. In subsequent years, they decide whether to continue attending school or drop out. Children under the age of 16 are not allowed to work, so if they do not attend school, they are assumed to be at home.[16]

[14] In 1979, there were 1846 private primary schools, but by 1982, just 1 year after vouchers were introduced, the number had increased to 2285.

[15] A similar assumption is made in a dynamic schooling model developed in Attanasio, Meghir, and Santiago (2001).

[16] In our data, it is uncommon for youth below age 16 to work for pay.

The transition to secondary school occurs at age 14 when individuals decide, from the same three schooling options, what type of secondary school to attend. Individuals can choose a secondary school type that is either the same or different from their primary school type. They incur a utility cost of transitioning from primary to secondary school that depends on the type of secondary school in relation to the type of primary school.[17] Individuals who complete 12 years of school make a choice about whether to attend college. If they attend college, they continue to make choices each year about whether to keep attending for up to 5 years. We assume that once an individual leaves school, he/she does not return.[18]

Starting at age 16, individuals receive earnings offers in every period that depend on their years of education completed thus far, on the type and number of years of primary and secondary school attended, on the number of years attended before and after the voucher reform was introduced, and on labor market experience, which accumulates endogeneously. Individuals can choose to continue with school, accept the earnings offer and work or be unemployed, in which case they get the utility associated with the leisure option. The model does not incorporate a savings decision, both for reasons of simplification and because few individuals in our sample report significant levels of voluntary savings.[19]

Also, all schooling options are available to all individuals, even if payment of tuition results in negative utility, and, in that sense, there are no liquidity constraints restricting choices. However, as previously noted, the model incorporates unobservable heterogeneity, and individuals who do not expect to get a high monetary return or who do not get a high nonpecuniary benefit from the higher cost private schooling options will not choose those options. For these reasons, individuals from poorer backgrounds will tend not to choose the more expensive private schooling options.

The unobserved heterogeneity takes the form of discrete unobserved types, as in Heckman and Singer (1984). Let μ_k be an indicator variable that equals 1 if the individual is of type k, where $k \in \{1, 2, 3\}$. The probability of being a particular type depends on family background variables that include parents' education, family socioeconomic background during the time when the individual was growing up, the number of siblings, and the individual's 10-year birth cohort. These variables constitute the model's initial conditions. The state space consists of the schooling history pertinent to current period decisions (type of primary education, type of secondary education, number of years of primary education pre-/post-voucher program, number of years of secondary education pre-/post-voucher program, number of years of college education) as well as accumulated labor market experience.

[17]This cost can be thought of as capturing costs of transferring from one school system to another, for example, the costs of being in a new environment and having to make new friends.

[18]In the Ben-Porath (1967) model, where individuals choose when to invest in schooling, it is optimal to take schooling at the beginning of the lifetime to maximize the time period over which to reap the returns from schooling. We impose the simplifying assumption that individuals cannot return to school, in part because our data record the total years of education completed and not the entire school attendance history.

[19]Chile has a privatized pension system that requires individuals to save 10% of their earnings to their pension account. Pension savings constitutes the primary form of savings for most people.

During the ages (a) when the individual has the option of attending primary school, the current period alternative-specific utility functions (U^i_{ak}) associated with the different schooling types for a person of type k are

$$U^S_{ak} = \sum_{k=1}^{K} \mu_k b^S_{1k} - T^S_1 1(v_a = 0) + \delta^S_1 1(R_1 = 0) + \delta^S_2 1(R_1 = 0)1(v_a = 0) + \varepsilon^S_a, \quad (1)$$

$$U^{NS}_{ak} = \sum_{k=1}^{K} \mu_k b^{NS}_{1k} + \delta^{NS}_1 1(R_1 = 0) + \delta^{NS}_2 1(R_1 = 0)1(v_a = 0) + \varepsilon^{NS}_a, \quad (2)$$

$$U^M_{ak} = \sum_{k=1}^{K} \mu_k b^M_{1k} + \delta^M_1 1(R_1 = 0) + \delta^M_2 1(R_1 = 0)1(v_a = 0) + \varepsilon^M_a, \quad (3)$$

where $1(\cdot)$ denotes a function that equals 1 if the expression in parentheses is true.

Variable b^i_{1k} ($i = S, NS, M$) is a psychic cost (consumption value) of attending different types of primary school that varies according to unobserved type; T^S_1 is the tuition cost at a subsidized primary school. The indicator variable $1(v_a = 0)$ equals 1 if the family is not eligible for a voucher at the child's age a, in which case the family pays the tuition cost at a subsidized private school. For nonsubsidized private schools, the tuition cost parameter cannot be separately identified from the utility parameter, so b^{NS}_{1k} represents utility net of the tuition cost. Variable R_1 is an indicator that takes the value 1 if the individual lives in the capital city, Santiago, which is home to about half of Chile's population. The parameters δ^i_1 ($i = S, NS, M$) represent transportation costs of attending school for individuals living outside of Santiago. Transportation costs are allowed to differ outside the capital, because there is much greater availability of private schools in Santiago along with good public transportation options. We also allow transportation costs of attending different types of schools to vary pre- and post-voucher reform, because of the previously described large expansion in the supply of private subsidized schools following the reform. There is a vector of preference shocks ($\varepsilon^S_a, \varepsilon^{NS}_a, \varepsilon^M_a$) associated with the different types of primary schooling. Let $d^S_1 = 1$ if private subsidized primary school is attended and let $d^{NS}_1 = 1$ if private nonsubsidized primary school is attended (else the indicator variables equal 0). Similarly, let $d^S_2 = 1$ if private subsidized secondary school is attended and let $d^{NS}_2 = 1$ if private nonsubsidized secondary school is attended.

The utility associated with the different secondary school choices depends on preference parameters (b^i_{2k}), tuition costs (T^S_2), costs of switching types of schools ($\rho^{\text{prim,sec}}$, prim $\in \{M, S, NS\}$, sec $\in \{M, S, NS\}$), and region of residence (R_1):

$$\begin{aligned} U^S_{ak} = &\sum_{k=1}^{K} \mu_k b^S_{2k} - T^S_2 1(v_a = 0) \\ &+ \rho^{M,S}(1 - d^S_1)(1 - d^{NS}_1)1(E_a = 9) + \rho^{S,S} d^S_1 1(E_a = 9) \\ &+ \rho^{NS,S} d^{NS}_1 1(E_a = 9) + \tau_1 \delta^S_1 1(R_1 = 0) \\ &+ \tau_2 \delta^S_2 1(R_1 = 0)1(v_a = 0) + \varepsilon^S_a, \end{aligned} \quad (4)$$

$$U_{ak}^{NS} = \sum_{k=1}^{K} \mu_k b_{2k}^{NS} + \rho^{M,NS}(1-d_1^S)(1-d_1^{NS})1(E_a=9) + \rho^{S,NS} d_1^S 1(E_a=9)$$
$$+ \rho^{NS,NS} d_1^{NS} 1(E_a=9) + \tau_1 \delta_1^{NS} 1(R_1=0) \tag{5}$$
$$+ \tau_2 \delta_2^{NS} 1(R_1=0)1(v_a=0) + \varepsilon_a^{NS},$$

$$U_{ak}^{M} = \sum_{k=1}^{K} \mu_k b_{2k}^{M} + \rho^{M,M}(1-d_1^S)(1-d_1^{NS})1(E_a=9) + \rho^{S,M} d_1^S 1(E_a=9)$$
$$+ \rho^{NS,M} d_1^{NS} 1(E_a=9) + \tau_2 \delta_1^{M} 1(R_1=0) \tag{6}$$
$$+ \tau_2 \delta_2^{M} 1(R_1=0)1(v_a=0) + \varepsilon_a^{M}.$$

Our parameterization of transportation costs assumes that the transportation cost to attend secondary school is a fixed fraction of the cost of attending primary school for all types of schools, with the fraction denoted by τ_1 in the pre-voucher reform time period and by τ_2 in the post-voucher reform time period.[20]

After the individual completes at least 2 years of school, there is the option to drop out and stay home (leisure). After age 16, there is also the option to work. To better capture the pattern in the data of some periods of unemployment prior to the first job, the model incorporates a job search cost that is only incurred with the first job (when experience $x_a = 0$) and that depends on the level of educational attainment E_a (<8 years, 8–11 years, and 12 or more years). Denote the job search costs for the different education levels by ψ^{E_a}. The utility from working is earnings minus any job search cost:

$$U_{ak}^{W} = w_{ak} - 1(x_a = 0)\psi^{E_a}.$$

The utility from leisure depends on preference parameters and a leisure preference shock:

$$U_{ak}^{L} = \sum_{k=1}^{K} \mu_k b_k^L + \varepsilon_a^L.$$

An individual who finishes high school can work, stay home, or attend college. While attending college, he gets utility

$$U_{ak}^{C} = \sum_{k=1}^{K} \mu_k b_k^C + \delta_1^C 1(R_1=1) + \varepsilon_a^C,$$

where b_k^C is the psychic benefit net of costs from college and δ^C is the transportation cost incurred by those who live outside the Santiago region. After completing school, individuals choose between staying at home or working.

[20]The assumption that the relative cost of attending primary to secondary school is fixed (at potentially different values before and after the reform) was made to reduce the number of model parameters in the estimation problem.

In the model, individuals may attend private instead of public schools, because they get higher utility, because of differences in the costs of attendance, and/or because private schooling generates higher future earnings returns. Let E_a^P denote the number of years of primary school attended and let E_a^S denote the number of years of secondary education. Some individuals in the sample completed their schooling before the voucher program was introduced, while others had the option of using the vouchers over part or all of their schooling careers. To allow for changes in the returns to all types of education after the voucher program was introduced, we distinguish years of education pre- and post-voucher. Let $E_a^{P,v=0}$ and $E_a^{S,v=0}$ denote the number of years of primary and secondary education attended prior to the voucher program, and let $E_a^{P,v=1}$ and $E_a^{S,v=1}$ denote the number of years attended after introduction of vouchers. Total years equals

$$E_a^P = E_a^{P,v=0} + E_a^{P,v=1},$$
$$E_a^S = E_a^{S,v=0} + E_a^{S,v=1}.$$

The number of years of college education completed as of age a is denoted by G_a.

We assume that the amount of human capital embodied in a person depends on educational attainment, type of primary and secondary schools attended, how much schooling was obtained before and after the introduction of vouchers, and the amount of labor market experience x:

$$H_{ak} = \varphi(E_a^{P,v=0}, E_a^{P,v=1}, E_a^{S,v=0}, E_a^{S,v=1}, G_a, x_a, d_1^S, d_1^{NS}, d_2^S, d_2^{NS}, \mu_k).$$

The earnings offer equation is the product of the price paid per unit of human capital and the amount of human capital possessed by the person. We also introduce a stochastic term ε_a^W to capture additional sources of heterogeneity in earnings offers:

$$w_a = p_H H_a e^{\varepsilon_a^W}.$$

Taking logs and assuming that the log human capital production equation is linear in years of schooling and quadratic in work experience, we obtain the log earnings equation

$$\begin{aligned}\ln w_a = {} & \sum_{k=1}^{K} \mu_k \beta_{0k} + \sum_{k=1}^{K} \mu_k \pi_{0k} 1(R_1 = 1) + \beta_1 E_a^P (1 - d_1^S)(1 - d_1^{NS}) \\ & + \gamma_1 E_a^{P,v=1}(1 - d_1^S)(1 - d_1^{NS}) + \beta_1^S E_a^P d_1^S + \gamma_1^S E_a^{P,v=1} d_1^S \\ & + \beta_1^{NS} E_a^P d_1^{NS} + \gamma_1^{NS} E_a^{P,v=1} d_1^{NS} + \beta_2 E_a^S + \gamma_2 E_a^{S,v=1} + \beta_2^S E_a^S d_2^S \\ & + \gamma_2^S E_a^{S,v=1} d_2^S + \beta_2^{NS} E_a^S d_2^{NS} + \gamma_2^{NS} E_a^{S,v=1} d_2^{NS} + \beta_3 G_a + \beta_3^{NS} G_a \\ & + \beta_4 x_a + \beta_5 x_a^2 + \varepsilon_a^W.\end{aligned} \tag{7}$$

In logs, the price of human capital is incorporated into the intercept, β_{0k}. The intercept is allowed to depend on unobserved types to capture permanent unobservable heterogeneity across individuals. The parameter π_{0k} captures the difference in earnings level between the Santiago and non-Santiago regions. The β coefficients refer to

the returns to different types of education prior to the introduction of the voucher program. The specification is more general than a standard Mincer-type earnings equation in that the returns to primary, secondary, and college years of schooling may differ. The γ coefficients represent the change in the schooling return after the introduction of the voucher reform, that is, the return to schooling post-reform is given by $\beta + \gamma$. The γ coefficients allow for the possibility that the voucher reforms changed the quality of all types of schools. For example, increased competition may have improved the quality of both public and private schools. On the other hand, the voucher program could also have drawn some of the better teachers out of the public school system, lowering public school quality. Thus, the coefficient γ could be either positive or negative.[21]

Individuals differ in terms of the timing of the voucher program with respect to their schooling career. For example, an individual may have attended 5 years of primary school pre-voucher, and 3 years primary and all of secondary school post-voucher. The coefficients β_1^{NS} and β_1^{S} (γ_1^{NS} and γ_1^{S}) capture the premium that individuals receive in the labor market for attending a private primary school; this earnings premium is allowed to differ by type of school (nonsubsidized verses subsidized). The coefficients β_2^{NS} and β_2^{S} (γ_1^{NS} and γ_1^{S}) capture the premium for having attended either a subsidized or nonsubsidized private secondary school. If an individual attends secondary school, then there are nine different schooling type combinations possible: public primary and secondary; public primary and private subsidized secondary; public primary and nonsubsidized private secondary; subsidized private primary and public secondary; subsidized private primary and private subsidized secondary; subsidized private primary and private nonsubsidized secondary; nonsubsidized private primary and public secondary; nonsubsidized private primary and subsidized secondary; subsidized secondary and nonsubsidized secondary. The coefficients β_3 and β_3^{NS} represent the earnings return for each year of college attended, which is allowed to differ depending on whether an individual attended a nonsubsidized private secondary school.[22] The coefficients β_4 and β_5 represent the market return to actual labor market experience, where the experience $x_a = \min(\text{actual experience}, 15)$.[23]

The maximized present discounted value of lifetime utility at age a, the value function, is given by

$$V(\Omega(a), a) = \max_{d_j(a) \in K(a)} E\left\{ \sum_{\tau=a}^{A} \beta^{\tau-a} U_a^j \middle| \Omega(a) \right\},$$

[21]Our specification allows for a discrete change in the return to schooling at the time of the voucher reform. It is of course plausible that some quality changes within the schools took place more gradually, but we adopt the discrete change specification to minimize the need for additional parameters and to facilitate the interpretation of the voucher reform impacts. In support of our specification, as noted in Section 1, there were radical changes to the education sector that took place in the year 1981 and the supply of private education responded fairly immediately.

[22]Individuals who attended nonsubsidized private secondary schools are more likely to attend the most elite universities in Chile, which are University of Chile and Catholica University.

[23]This specification assumes that returns to experience are increasing up to 15 years and then are zero. It was chosen instead of a quadratic, so that the returns to experience did not become negative at some point.

where $K(a)$ is the set of alternatives available to the individual at age a and A is the terminal age of the model, assumed to be age 62. The expectation is taken over the distribution of preference and earnings shocks.

Last, we note that the model estimated in this paper is partial equilibrium and does not incorporate any dependence of market earnings on aggregate stocks of human or physical capital. Arguably, general equilibrium effects could be important given that the voucher reform was implemented on a nationwide scale. Increases in the aggregate supply of skill due to the reform may have put downward pressure on the market returns to skill. One reason that we do not estimate a general equilibrium model is because of data limitations. Our data pertain to a random sample of Chilean men for the survey years (2002 and 2004) and would not be a reliable source of information about aggregate stocks of human capital in previous decades. A second reason is that the literature on the estimation of dynamic general equilibrium (GE) schooling models is still in its infancy. There have been some interesting studies using U.S. data, but the evidence from these studies on the relative importance of incorporating GE effects in dynamic schooling models is mixed; see, for example, Heckman, Lochner, and Taber (1998), Lee (2005), and Lee and Wolpin (2006).[24] Although our model is partial equilibrium, it does accommodate nonstationarity in the earnings distribution that might arise, for example, from secular changes in the types of job opportunities facing successive birth cohorts. Earnings offers depend on unobserved types, and the distribution of the unobserved types varies with 10-year birth cohorts and with family background characteristics. Thus, different birth cohorts experience different earnings offer distributions for reasons other than the voucher reform.

4. Model solution and estimation

The solution to the optimization problem is a set of decision rules that relate the optimal choice at any age a, from among the feasible set of alternatives, to elements of the state space. Recasting the problem in a dynamic programming framework, the value function can be written as the maximum over alternative-specific value functions, $V^j(\Omega(a), a)$, that is, the expected discounted value of alternative $d_j(a) \in K(a)$ that satisfies the Bellman equation

$$V(\Omega(a), a) = \max_{d_j(a) \in K(a)} \big[V^j(\Omega(a), a)\big],$$

$$V^j(\Omega(a), a) = \begin{cases} U^j(a, \Omega(a)) \\ \quad + \beta E\big(V(\Omega(a+1), a+1) | d_j(a) = 1, \Omega(a)\big), & \text{for } a < A, \\ U^j(A, \Omega(A)), & \text{for } a = A. \end{cases}$$

The solution of the optimization problem is not analytic, so the model is solved numerically. The solution consists of values of $E(V(\Omega_{t+1}, t+1) | d_j(a), \Omega(a))$ for all j and

[24]The different results are not that surprising given that there is substantial heterogeneity across studies in how GE effects are incorporated, for example, how skills are defined, how aggregate stocks are determined, how the aggregate production function is specified, and how individuals are assumed to form expectations about future earnings.

elements of $\Omega(a)$. We refer to this function as the Emax. The solution method is by backward recursion, beginning with the last period, A. The multivariate integrations necessary to calculate the expected value of the maximum of the alternative-specific value functions at each state point are performed by Monte Carlo integration over the shocks. The state space is manageable, so we evaluate the value of the Emax function at every possible state point without having to use Emax approximation methods.

The model is estimated by simulated maximum likelihood. Let O_{it} represent the outcomes (education choices, work choices, observed earnings) of individual i at age a. Also, let I_i denote the set of initial conditions for that individual (family background variables, type of primary school attended). Let $\Pr(\mu_k = 1|I_i)$ denote the type probability, which depends on initial conditions (family background, which includes socioeconomic status, parental education levels, and numbers of siblings, and 10-year birth cohort indicators). The likelihood for individual i can be written as the product over the age-specific choice probabilities, integrating over the unobserved type:

$$= \sum_{k=1}^{K} \prod_{a=a_0}^{A} \Pr(O_{ia}|O_{ia-1}, \ldots, O_{ia_0}; \mu_k = 1, I_i) \Pr(\mu_k = 1|I_i)$$

$$= \sum_{k=1}^{K} \prod_{a=a_0}^{A} \Pr(d^j(a)|w_a, \Omega(a), I_i) f(w_a|\Omega(a), I_i, \mu_k = 1) \Pr(\mu_k = 1|I_i),$$

where $f(w_a|\Omega(a), I_i, \mu_k = 1)$ is the earnings density. The overall likelihood takes the product over the individual likelihoods. In implementation, there are assumed to be three types and the type probability is specified as multinomial logistic. A supplemental appendix, available online (Bravo, Mukhopadhyay, and Todd (2010)), provides a detailed description of the methods used to simulate the likelihood.

The model parameters enter the likelihood through the choice probabilities that are computed from the solution of the dynamic programming problem. Subsets of parameters also enter through the earnings density. The maximization of the likelihood function iterates between solving the dynamic program and calculating the likelihood.[25] We obtain standard errors of the parameter estimates by the inverse of the average of the product of the score matrices, where the derivatives of the log likelihood are evaluated numerically.[26]

5. Empirical results

5.1 *Data*

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

[25]For a description of methods used to estimate discrete choice dynamic programming models, see Keane and Wolpin (1994). Solving the model and optimizing over the 108 parameters is computationally fairly intensive. For this reason, computation was done on a parallel linux cluster with 56 processors using the asynchronous parallel pattern search algorithm (APPSPACK; see Gray and Kolda (2004)).

[26]This is known as the BHHH estimator (Berndt et al. (1974)). To obtain numerical derivatives, we use a step size parameter equal to 1% of the parameter estimate.

(HLLS). In 2004, it administered a follow-up survey and changed its name to the Encuesta de Protección Social (EPS; translation, Social Protection Survey). The data from the two surveys 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, and bank account savings, as well as more limited information on health, durable 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 information back to 1981, as well as questions on educational attainment, family background (number of siblings, parent's education, poverty status during adolescence), type of primary and secondary school attended, and location (geographic region) of schools attended. The Appendix contains a description of the sampling frame for the 2002 and 2004 surveys.

Our analysis sample consists of 3910 male individuals who were at most 21 years old in 1981 and for whom we observe educational attainment and an entire labor force participation history. We have a total of 107,394 person-year observations on these individuals.

5.2 *Descriptive statistics*

Table 1 shows the means of variables used in our analysis, for the complete sample and by type of primary school attended. The average age is 30.6 years and the average education level 11.0 years. A comparison of the last three columns shows that individuals who attended municipal primary schools attain on average 10.5 years of schooling. Those who attend private primary schools complete substantially more education, with an average of 12.8 years for those attending private subsidized primary schools and 14.1 years for those attending private nonsubsidized primary schools. Roughly a third of our sample resided in Santiago (the capital city) at the time of attending school. Also, more than half of the people who report attending private primary schools (subsidized or nonsubsidized) did so in Santiago. Average annual earnings in our sample is $4901 in 2002 U.S. dollar equivalents.[27] Average earnings are nearly $1000 higher for those who attended subsidized primary school rather than municipal school and are nearly double for those attending nonsubsidized private school ($9767 on average).

Table 1 also provides information on the family background of the individuals. The men in our sample attain much higher average education levels than did their parents. On average, the mothers have 7.1 years of education and the fathers have 7.8 years. Parental education levels are higher by 0.3–0.5 years for individuals who attended private subsidized primary school than for municipal school attendees, and almost 2 years higher for private unsubsidized primary school attendees. Respondents were also asked about the poverty status of their family while growing up, which was reported in four categories: indigent, poor, good, and very good. Only a small proportion (2.5%) report their family background as indigent. The majority report poor (34.8%) or good (59.2%),

[27]We set to missing reported earnings below $1140 which is equivalent to 1000 hours of work at the minimum earnings rate prevailing in Chile in 2002. This implies that we set 366 earnings observations equal to missing out of a total of 9191 observations.

TABLE 1. Descriptive statistics (standard deviation in parentheses).

	Overall	Municipal Primary	Private Subsidized Primary	Private Unsubsidized Primary
Age	30.6	31.3	27.1	29.2
	(7.2)	(7.1)	(7.0)	(7.6)
Years of education	11.0	10.5	12.8	14.1
	(3.4)	(3.3)	(2.6)	(2.8)
Attended primary in Santiago	35.3	30.3	57.0	55.6
	(0.48)	(46.0)	(49.6)	(49.8)
Attended secondary in Santiago	31.1	25.6	54.1	56.1
	(46.3)	(43.7)	(49.9)	(49.8)
Annual earnings (in 2002 dollars)	4901	4565	5477	9767
	(4515)	(3963)	(4075)	(9381)
Mother's education	7.1	6.9	7.3	8.7
	(3.77)	(3.60)	(4.1)	(4.9)
Father's education	7.8	7.7	8.2	9.7
	(4.1)	(3.9)	(4.3)	(5.1)
Family				
Indigent	2.5	2.6	2.4	2.6
	(15.7)	(15.8)	(15.2)	(16.1)
Poor	34.8	35.7	30.7	31.2
	(47.6)	(47.9)	(46.2)	(46.4)
Good	59.2	58.5	63.0	60.3
	(49.2)	(49.3)	(48.3)	(49.1)
Very good	3.4	3.2	4.0	5.8
	(18.3)	(17.7)	(19.6)	(23.5)
Number of siblings	3.7	3.8	3.2	3.3
	(2.7)	(2.7)	(2.6)	(2.8)
Number of individuals	3910	3168	553	189

and a small proportion (3.4%) report very good. Individuals who attend private schools are less likely to report an indigent or poor background. On average, the individuals in our sample have 3.7 siblings, with slightly fewer (3.3 on average) for private school attendees.

As seen in Figure 1, following the voucher reform in 1981, the percentage of individuals attending municipal schools decreased dramatically. The decrease was most pronounced in the first 5 years, but continued thereafter. Correspondingly, the percentage attending private subsidized primary schools increased. The percentage attending private nonsubsidized schools exhibits an increase over the 1990–2000 period followed by a slight decline. The percentage choosing private nonsubsidized schools ranges from a low of 5.1 in 1981 to a high of 9.5 in 1996.

Figure 2 shows the educational attainment distribution, overall and by type of primary school attended. Individuals who attended municipal schools are much more likely to be in the lowest education categories or to have dropped out of primary school. Of this group, 31% complete exactly twelfth grade and 25% go beyond. Individuals who attend private subsidized primary schools are more likely to finish twelfth grade (34%)

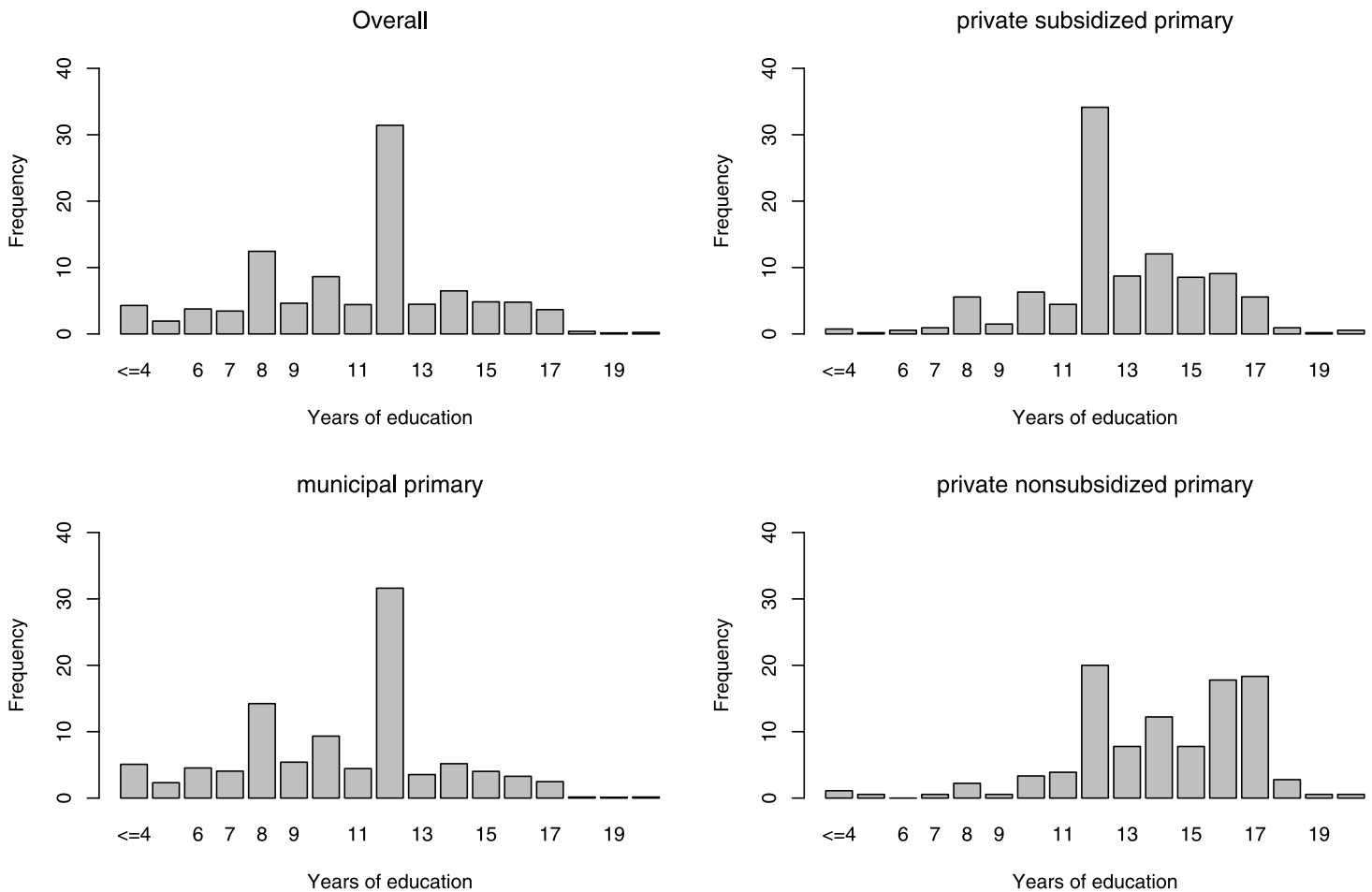

FIGURE 2. Education distribution, overall and by type of primary attended.

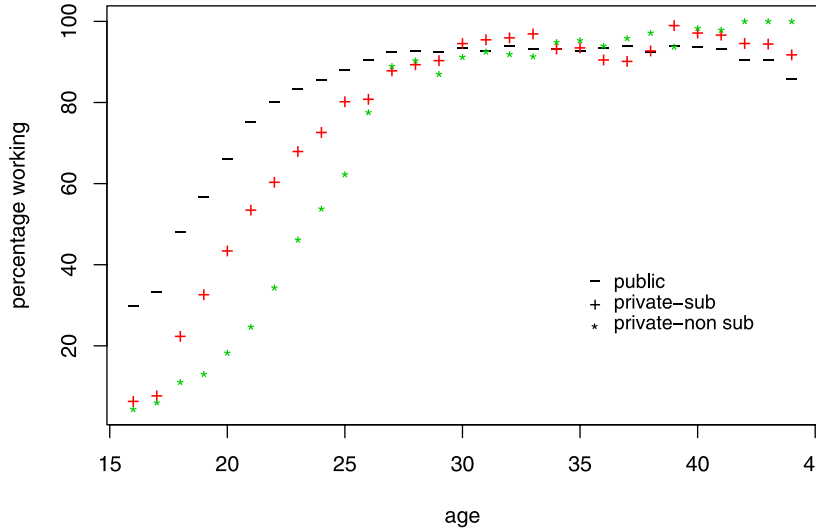

FIGURE 3. Percentage of people who are working by age and type of primary school.

or go beyond (46%), but their educational attainment is not nearly as high as that of individuals attending nonsubsidized primary schools, 68% of whom go to college.

Figure 3 graphs the percentage of people who are working by age and by type of primary school attended, where the sample is restricted to individuals who have completed their schooling and are legally permitted to work (age 15 and older). The differences in working rates are most pronounced in the 20s, when those who attended municipal schools have, for the most part, left school and exhibit the highest rates of working. For example, at age 24, 86% of municipal school attendees are working in comparison to 73% of private subsidized primary attendees and only 54% of private nonsubsidized. Starting at around the mid 30s, though, the working rates of individuals who attend nonsubsidized private schools surpass those of the other groups and reach close to 100%, while those who attended either municipal or private subsidized primary schools have lower rates of around 93%. There is a decline in working rates in the late 40s among those who attended municipal or subsidized private primary schools.[28]

Figure 4 graphs the age–earnings relationship by educational attainment categories and type of primary school attended.[29] Among those completing less than 8 years of education, municipal school attendees have a flatter age–earnings relationship than private school attendees. For individuals who completed 8–11 years of school or who completed high school only (12 years), the age–earnings relationship is comparable across the three different schooling types, with no clear evidence of an earnings premium for having attended a private primary school. For those who complete more than 12 years of schooling, earnings are comparable for those who attended municipal or

[28]The model we estimate can generate some decline in working rates at older ages when there is no longer any additional gain from accumulating more labor force experience.

[29]The age–earnings curves are smoothed using local regression. A bandwidth of 5 years was used for the plots.

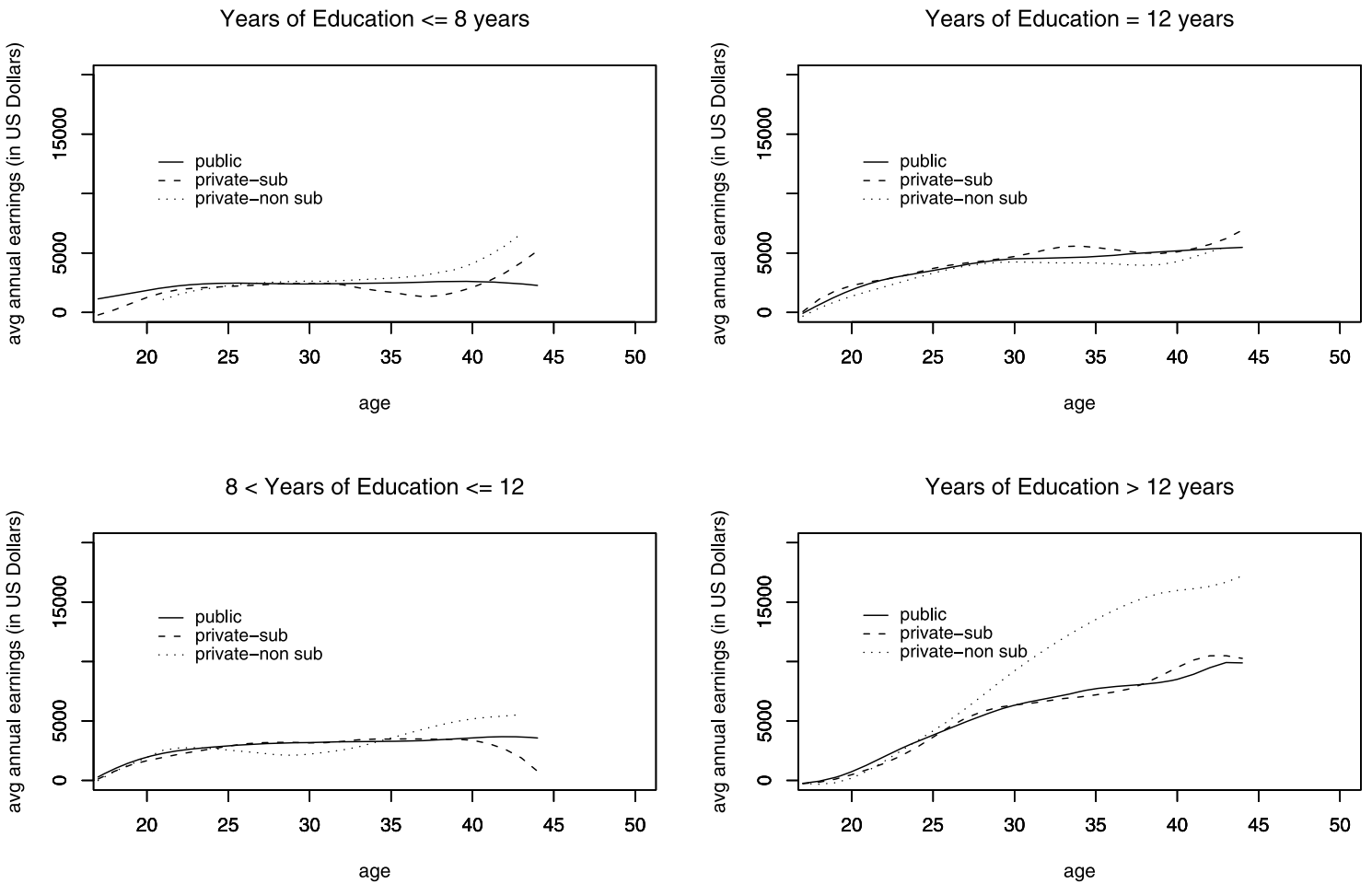

FIGURE 4. Smoothed earnings–age relationship by education class and schooling type.

subsidized private schools, but are much higher for those who attended nonsubsidized private schools. This difference is most likely attributable to differences in the types of colleges attended, with a higher proportion of private nonsubsidized secondary school students attending the premiere universities (such as Catholica University and University of Chile). Earnings also increase with age with a rate of increase that is higher for those with higher schooling completion levels.

As described in the previous section, our specification of the earnings offer equation allows the returns to schooling to depend on type of school attended and whether attended before or after the voucher reform. This accommodates potential quality differences between the different types of schools as well as changes in quality arising from the reforms. Although we do not have time series data on empirical measures of school quality that date back to the time of the voucher reforms, we do have some recent information on the characteristics of teachers who teach in the different types of schools that we obtained from a 2006 survey of teachers.

Table 2a compares the characteristics of teachers in municipal schools, subsidized private schools, and nonsubsidized private schools. Teachers at municipal schools have the highest rate of postgraduate education and are more likely to have received training over the previous 5 years. According to several measures of job satisfaction, teachers at private schools report higher rates of satisfaction. The table shows two measures of satisfaction: whether teachers think they are given sufficient time to prepare their classes and whether they participate in curriculum development. Teachers at public schools are more likely to have had a medically related absence and are much less likely to have access to or use a computer to do their work.

Table 2b compares the median hourly earnings by type of establishment and by age of the teacher. Public schools offer the lowest starting salaries, but have the greatest earnings increment with age. Private subsidized schools offer higher starting salaries, but have less growth with age than public schools. Overall median earnings are lower for private subsidized schools than for public schools, which partly reflects the relatively younger ages of private school teachers. Nonsubsidized private schools pay salaries that are 10–20% higher than other types of schools. These comparisons suggest that there

Table 2a. Characteristics of teachers by type of establishment. Sample: Teachers in the longitudinal teacher survey.

	Municipal	Private Subsidized	Private Non-subsidized
% of Teachers with postgraduate studies	38.5	33.7	37.5
% of Teachers receiving training in years 2000–2005	81	79.1	72.9
% of Teachers with sufficient time for class preparation	19	31	41
% of Teachers participating in curriculum development	26	31	46
% of Teachers absent for medical reasons (in 2004)	37	31	27
% of Teachers who work regularly with computers as part of their job	60	74	76
% of Teachers who have access to a computer for teaching work	61	73	81

TABLE 2b. Median hourly wage by type of establishment and teacher age.

	Age 20–29	Age 30–39	Age 40–49	Age 50–59	Age 60+	All Ages
Municipal	7666	9090	10,681	12,666	14,000	11,363
Private subsidized	8823	9642	10,250	10,978	11,538	10,000
Private nonsubsidized	10,833	11,250	13,589	14,583	16,666	12,500

Note: Wages are in 2007 Chilean pesos. The exchange rate is approximately 500 pesos per U.S. dollar.

are important differences in the characteristics of teachers who teach in different types of schools, although it is not obvious how these differences translate into school quality differences.

5.3 *Reduced form estimated decision rule models*

In Tables 3, 4, and 5, we present estimates of choice models that relate the decision variables in the behavioral model (school attendance, type of school attended, educational

TABLE 3. Approximate decision rule model for years of education (standard errors in parentheses).

Variable[a]	Estimated Coefficient
Intercept	7.705
	(0.425)
Years exposed to voucher[b]	0.081
	(0.018)
Mother's education	0.055
	(0.023)
Father's education	0.032
	(0.022)
Number of siblings	−0.026
	(0.023)
Family background poor	1.047
	(0.381)
Family background good	1.413
	(0.381)
Family background very good	1.113
	(0.500)
Resided in Santiago during primary or	1.524
secondary school years	(0.127)
Birth cohort 1970–1979	0.191
	(0.233)
Number of observations	2907
R-squared	0.095

[a]The specification also includes indicator variables for whether information on mother's education, father's education, or region of residence is missing. The omitted family background category is "indigent" and the omitted birth cohort is 1960–1969. The sample is restricted to persons age 24 or older in 2002 or 2004 (whenever first observed), who are likely to have completed their schooling.

[b]Total number of years exposed to voucher prior between ages 6 and 18.

Table 4. Multinomial logit model for the probability of choosing subsidized or nonsubsidized primary relative to municipal primary choice (standard errors in parentheses).

Variable[a]	Subsidized Primary Choice	Odds Ratio	Nonsubsidized Primary Choice	Odds Ratio
Intercept	−2.99	0.05	−4.53	0.011
	(0.36)		(0.56)	
Voucher exposure	0.052	1.05	0.035	1.04
	(0.016)		(0.025)	
Mother's education	0.007	1.01	0.087	1.09
	(0.017)		(0.025)	
Father's education	0.018	1.02	0.062	1.06
	(0.016)		(0.026)	
Number of siblings	−0.043	0.96	−0.031	0.97
	(0.020)		(0.032)	
Family background poor	−0.124	0.88	−0.124	0.88
	(0.322)		(0.487)	
Family background good	−0.070	0.93	−0.268	0.76
	(0.320)		(0.487)	
Family background very good	0.054	1.06	0.113	1.12
	(0.399)		(0.578)	
Resided in Santiago during	1.031	2.80	1.10	3.00
primary or secondary school years	(0.097)		(0.155)	
Born 1970–1979	0.249	1.28	−0.216	0.81
	(0.221)		(0.348)	
Born 1980–1989	0.618	1.85	0.055	1.06
	(0.271)		(0.433)	
Number of observations	3910			

[a]The specification also includes indicator variables for whether information on mother's education, father's education, or region of residence is missing.

attainment, and work) to the state variables. These models approximate the decision rules without imposing the structure of the behavioral model, although they do not account for unobservable heterogeneity. Table 3 shows the estimated coefficients from regressing schooling attainment on the state variables, which include the total number of years the individual was exposed to the voucher program at any point over ages 6–18.[30]

Individuals who attended school when vouchers were available, ceteris paribus, have higher educational attainment, by about 0.08 years for each year of exposure to the voucher program. Not surprisingly, individuals whose parents (mothers and/or fathers) have more schooling also tend to achieve higher schooling attainment levels, with a larger estimated coefficient on mother's education than on father's. Also, as expected, individuals from less poor families have significantly higher educational attainment levels than individuals from indigent families (the omitted category). The number of siblings is not a significant predictor of schooling attainment, conditional on the other included variables. Residing in the city of Santiago is associated with 1.5 years higher attainment. Individuals born later also have higher educational attainment.

[30]For example, if the individual was in second grade when the program was introduced, the exposure is 10 years.

TABLE 5. Decision rule model for working, probit model (standard errors in parentheses).

Variable[a]	Estimated Coefficient	Mean Marginal Effect
Intercept	−1.86	—
	(0.078)	
Years of education	0.020	0.004
	(0.002)	
Attended subsidized private primary	−0.123	−0.023
	(0.023)	
Attended nonsubsidized private primary	−0.224	−0.041
	(0.036)	
Voucher exposure (in years)	0.103	0.019
	(0.003)	
Labor force experience (in years)	0.158	0.029
	(0.002)	
Born in 1970–1979 cohort	0.121	0.022
	(0.040)	
Born in 1980–1989 cohort	−0.106	−0.020
	(0.040)	
Mother's education	−0.003	−0.0005
	(0.003)	
Father's education	0.006	0.001
	(0.003)	
Number of siblings	0.010	0.002
	(0.003)	
Family background poor	−0.055	−0.010
	(0.047)	
Family background good	−0.104	−0.019
	(0.047)	
Family background very good	−0.092	−0.017
	(0.060)	
Resided in Santiago during primary or secondary school years	0.113	0.021
	(0.016)	
Number of observations	60,307	

[a]The specification also includes indicator variables for whether information on mother's education, father's education, family background, poverty status, region of residence, or number of siblings is missing. The sample is restricted to observations on individuals age 16 or older.

Table 4 presents coefficient estimates from a multinomial logit model for the choice of primary school type, where the estimates refer to the probability of attending a subsidized or nonsubsidized private primary school relative to a municipal school. The table also shows the odds ratio corresponding to each coefficient estimate. Voucher exposure is associated with a statistically significant increase in the probability of choosing the subsidized primary private school type, without any significant change in the probability of choosing the nonsubsidized primary school type. Mother's and father's education are also statistically significant determinants of the probability of choosing a private unsubsidized school. Also, individuals with more siblings are less likely to attend private schools. Residing in Santiago while growing up makes it much more likely that an in-

dividual attends private primary school. In fact, ceteris paribus, individuals who grew up in Santiago are almost three times as likely to attend one of the private schooling types. The other family background variables are not significant predictors of the choice of primary school type.

Table 5 presents coefficient estimates from a probit model of the probability of working, where the sample includes all person-year observations for those 15 or older who are not in school. The third column shows the average of the individual estimated marginal effects. Ceteris paribus, more years of education increases the probability of working. Attending subsidized primary or unsubsidized private primary schools decreases the probability of working. Conditional on the other factors, voucher exposure is associated with a significant increase in the probability of working, as is having a father with more years of education, but being from a less poor family is associated with a lower probability of working. As expected, previous labor market experience significantly increases the probability of working in the current period. Last, residing in Santiago substantially increases the probability of working.

5.4 *Empirical results*

5.4.1. *Parameter estimates*

As described in Section 4, our specification of the earnings offer equation allows the earnings returns from schooling to depend on type of school attended (primary and secondary) and on whether attending before or after the voucher reforms. Table 6a shows the estimated earnings returns to primary, secondary, and college education (along with standard errors), where the primary school returns correspond to 2-year returns, and the secondary and college returns correspond to 1-year returns.[31] The earnings return to secondary school is more than twice as high as the return to primary school. A comparison of earnings returns associated with the pre- and post-voucher reform periods shows that the earnings returns to primary schooling increased after the reform in municipal and subsidized private schools. At the secondary school level, however, the estimated schooling returns are lower in the post-voucher period than the pre-voucher period in all types of schools. As previously noted, the private secondary schools built after the reform were thought to be of lower quality than the preexisting schools. Also, per-pupil expenditure declined in both primary and secondary schools in the decade following the reform, with the largest decline in secondary schools.[32] With regard to post-secondary education, the estimated returns are surprisingly low for individuals who did not attend nonsubsidized private schools and are only 3% per year for those who attended the nonsubsidized private schools.

[31]Standard errors are obtained by the square root of the diagonal elements of the inverse of the square of the score vector. The derivatives of the likelihoods are evaluated numerically.

[32]The decline in secondary schooling returns could also be related to a general equilibrium effect of rising stocks of human capital lowering the returns to human capital after the reform, although the model does not incorporate this sort of dependence.

TABLE 6a. Estimated wage offer parameters.

Parameter	Estimate	Parameter	Estimate
Return to municipal primary education		Rental rate on years of college education (β_3)	0.0035 (0.00044)
Pre-voucher (β_1)	0.0587 (0.007)		
Post-voucher ($\beta_1 + \gamma_1$)	0.0681 (0.009)		
Return to private subsidized primary education		Extra rental rate on years of college education for nonsubsidized school attendees (β_3^{NS})	0.033 (0.0046)
Pre-voucher (β_1^S)	0.0512 (0.007)		
Post-voucher ($\beta_1^S + \gamma_1^S$)	0.0585 (0.009)		
Return to private nonsubsidized primary		Labor market experience (β_4)	0.095 (0.014)
Pre-voucher (β_1^{NS})	0.0543 (0.007)	Experience squared (β_5)	−0.0028 (0.00035)
Post-voucher ($\beta_1^{NS} + \gamma_1^{NS}$)	0.0466 (0.007)		
Return to municipal secondary education		ln wage constant	
Pre-voucher (β_2)	0.0779 (0.010)	Type 1	6.87 (0.866)
Post-voucher ($\beta_2 + \gamma_2$)	0.0631 (0.008)	Type 2	7.87 (0.941)
		Type 3	7.19 (0.828)
Return to private subsidized secondary education		ln wage constant penalty for non-Santiago region	
Pre-voucher (β_2^S)	0.0812 (0.011)	Type 1	−0.071 (0.009)
Post-voucher ($\beta_2^S + \gamma_2^S$)	0.0712 (0.10)	Type 2	−0.040 (0.005)
		Type 3	−0.042 (0.006)
Rental rate on private nonsubsidized secondary			
Pre-voucher (β_2^{NS})	0.0736 (0.009)		
Post-voucher ($\beta_2^{NS} + \gamma_2^{NS}$)	0.0654 (0.009)		

As a point of comparison, Table 7 presents estimated coefficients obtained from an ordinary least squares (OLS) earnings regression that was estimated outside the model without controlling for unobserved heterogeneity. The OLS estimated rates of return to schooling are much higher than those reported in Table 6a, a pattern that is consistent

TABLE 6b. Estimated utility function parameters.

Parameter	Estimate	Parameter	Estimate
Utility from attending municipal primary school (b_{1k}^{M})		Utility from attending subsidized secondary school (b_{2k}^{S})	
Type 1	845.6	Type 1	279.3
	(114.0)		(29.8)
Type 2	5635.4	Type 2	3996.6
	(677.3)		(503.2)
Type 3	3010.7	Type 3	2240.2
	(415.8)		(302.6)
Utility from attending subsidized primary school (b_{1k}^{S})		Utility from attending nonsubsidized secondary school (net of any costs) (b_{2k}^{NS})	
Type 1	374.3	Type 1	79.0
	(49.2)		(9.8)
Type 2	5519.9	Type 2	3821.6
	(696.5)		(443.6)
Type 3	2862.5	Type 3	2102.5
	(376.7)		(270.3)
Utility from attending nonsubsidized primary school (net of any costs) (b_{1k}^{NS})		Utility from attending college (b_{k}^{C})	
Type 1	81.3	Type 1	−531.2
	(10.1)		(72.6)
Type 2	5402.9	Type 2	3843.4
	(679.7)		(479.8)
Type 3	2724.4	Type 3	1335.1
	(305.5)		(194.5)
Utility from attending municipal secondary school (b_{2k}^{M})		Utility from staying home (b_{k}^{L})	
Type 1	185.9	Type 1	320.6
	(28.6)		(43.6)
Type 2	3991.1	Type 2	4996.3
	(534.9)		(671.2)
Type 3	2166.5	Type 3	1552.3
	(266.1)		(195.7)

with the literature that structurally estimates dynamic schooling choice models.[33] This pattern suggests that much of the return to schooling estimated from an OLS regression can be accounted for by unobservable heterogeneity. Table 6a also reports estimates of the earnings intercept parameters and of the returns to labor market experience. Interestingly, the estimated returns to experience are higher than obtained in the OLS regression (Table 7).

[33]See, for example, estimated return to schooling parameters presented in Keane and Wolpin (1997) and Belzil (2007).

TABLE 6c. Estimated parameters related to costs of schooling and finding first job.

Parameter	Estimate	Parameter	Estimate
Cost of attending primary municipal school from outside of Santiago (δ_2^M)		Switching cost of changing from subsidized primary to municipal secondary ($\rho^{S,M}$)	−847.0 (107.1)
Pre-voucher	−225.6 (29.2)		
Post-voucher	−100.0 (12.0)		
Cost of attending primary subsidized school from outside of Santiago (δ_2^S)		Switching cost of changing from subsidized primary to subsidized secondary ($\rho^{S,S}$)	−11.0 (1.44)
Pre-voucher	−439.6 (58.8)		
Post-voucher	−281.6 (31.2)		
Cost of attending primary nonsubsidized school from outside of Santiago (δ_2^{NS})		Switching cost of changing from subsidized primary to nonsubsidized secondary ($\rho^{S,NS}$)	−562.4 (75.2)
Pre-voucher	−431.2 (53.6)		
Post-voucher	−243.5 (28.7)		
Net cost of primary subsidized school (T_1^S)	−105.6 (12.7)	Switching cost of changing from nonsubsidized primary to municipal secondary ($\rho^{NS,M}$)	−959.3 (127.6)
Net cost of secondary subsidized school (T_2^S)	−38.8 (5.2)	Switching cost of changing from nonsubsidized primary to subsidized secondary ($\rho^{NS,S}$)	−338.0 (46.3)
Ratio of secondary school cost to primary school cost		Switching cost of changing from nonsubsidized primary to nonsubsidized secondary ($\rho^{NS,NS}$)	−74.0 (9.57)
Pre-voucher (τ_1)	1.031 (0.142)		
Post-voucher (τ_1)	0.589 (0.073)		
Switching cost of changing from municipal primary to municipal secondary ($\rho^{M,M}$)	−3.87 (0.514)	Cost of finding first job if less than 9 years in school ($\psi^{\mathrm{Ea}<9}$)	−5020.4 (695.3)
Switching cost of changing from municipal primary to subsidized secondary ($\rho^{M,S}$)	−370.2 (52.1)	Cost of finding first job if 9–12 years of school ($\psi^{\mathrm{Ea}=9-12}$)	−8257.5 (1061.8)
Switching cost of changing from municipal primary to nonsubsidized secondary ($\rho^{M,NS}$)	−800.0 (112.6)	Cost of finding first job if more than 12 years of school ($\psi^{\mathrm{Ea}>12}$)	−7947.1 (1051.7)

Table 6d. Estimated standard errors of shocks.

Parameter	Estimate
Standard error of ln wage error term	0.380
	(0.049)
Standard error of preference shock for public school	955.2
	(118.0)
Standard error of preference shock for private subsidized school	535.5
	(62.3)
Standard error of preference shock for private nonsubsidized school	253.3
	(31.2)
Standard error of preference shock for home utility	1606.0
	(187.2)

Table 6e. Estimated parameters of the multinomial unobserved type probabilities (relative to type 3).

Type 1		Type 2	
Parameter	Estimate	Parameter	Estimate
Constant	0.498	Constant	0.725
	(0.067)		(0.091)
Father's education	0.015	Father's education	0.618
	(0.002)		(0.008)
Mother's education	0.008	Mother's education	0.00006
	(0.001)		(7.52E−06)
Family poor	−0.201	Family poor	−0.0195
	(0.022)		(0.0029)
Number of siblings	0.072	Number of siblings	−0.0074
	(0.012)		(0.0010)
Born in 1970s	−0.90	Born in 1970s	−0.250
	(0.093)		(0.031)
Born in 1980s	−2.745	Born in 1980s	−1.587
	(0.358)		(0.214)
Outside Santiago	0.195	Outside Santiago	−0.740
	(0.027)		(0.102)

Table 6b reports estimates of the utility function parameters, which vary with the unobserved type. There is substantial heterogeneity across types in the value associated with different kinds of schooling. Types 2 and 3 have higher valuation of all types of schooling, with type 2 having the highest valuation for primary, secondary, and college. All types tend to get higher utility from municipal primary relative to subsidized primary schools.[34] At the secondary level, the utility associated with municipal secondary and subsidized secondary schools is fairly comparable for types 2 and 3, while type 1 gets

[34]The nonsubsidized primary estimated cannot be directly compared to the other types, because the nonsubsidized estimated utility incorporates tuition costs. For the other types, the tuition costs are separately identifiable because of the presence of the voucher only in the post-reform time period.

TABLE 7. Estimated coefficients from OLS wage regression.

Variable	Coefficient	Robust Standard Error
Experience	0.065	0.005
Experience squared	−0.002	0.0002
College	0.171	0.010
Municipal primary before reform	0.112	0.025
Subsidized primary before reform	0.121	0.030
Nonsubsidized primary before reform	0.170	0.034
Municipal primary after reform	0.138	0.025
Subsidized primary after reform	0.139	0.026
Nonsubsidized primary after reform	0.116	0.032
Municipal secondary before reform	0.124	0.014
Subsidized secondary before reform	0.106	0.030
Nonsubsidized secondary before reform	0.197	0.038
Municipal secondary after reform	0.091	0.008
Subsidized secondary after reform	0.111	0.010
Nonsubsidized secondary after reform	0.155	0.020
Constant term	6.874	0.102

the highest relative utility from subsidized school. Type 2 has the highest valuation from staying home and type 1 has the lowest.

Table 6c reports estimates of the model parameters associated with the additional costs of attending schools for individuals outside of urban Santiago.[35] The costs of attending municipal schools are substantially lower than the costs of attending other types of schools, as might be expected given their wider availability. A comparison of the estimated costs pre- and post-reform shows that the costs of attending schools fell substantially following the reform, by about one-half, which is most likely attributable to the expansion in school availability. As indicated by the estimated τ_1 and τ_2 coefficients, which represent the costs of secondary schooling as a fixed fraction of the costs of primary schooling, the relative costs of attending secondary schooling declined in the post-voucher reform time period. In the simulations reported later in the paper, the decline in the costs of attending school plays an important role in increasing the duration of school attendance.

Table 6c also reports estimates of school-type switching costs for the primary–secondary school transition. As expected, the cost of staying in the same type of school (municipal, private subsidized, or private nonsubsidized) is estimated to be substantially lower than the cost of switching types of schools. The highest switching costs are associated with the transition from private subsidized or unsubsidized primary to municipal secondary and also with the transition from municipal primary to nonsubsidized primary. The costs are relatively lower for transiting from one type of private primary to another type of private secondary.

[35]For people living inside Santiago, any transportation costs would be incorporated into the net utility of attending school. The δ parameters represent additional transportion costs for people living outside of Santiago.

In addition, Table 6c reports the estimated perceived monetary benefit to families from the voucher (above the value of the respective types of schooling). The estimated benefit is lower than the actual value of the voucher at $105 at the primary level (for 2 years) and $38/year at the secondary level.[36] It is important to note that voucher amounts were not directly paid to the families, but were transferred directly to the schools based on enrollment numbers. The estimated benefit that families receive from the voucher need not equal the actual transfer amount for two reasons. One is that private schools received substantial governmental subsidies even before the voucher reform, equivalent to about 50% of per-pupil costs of municipal schools (Gallego and Hernando (2009)), so the private school tuition that families would have been paying before the voucher program would have been less than the voucher amount. Another reason is that families who take advantage of the voucher after the reform need not value it at the amount of the voucher.

The costs of finding a first job are reported in the bottom three rows of Table 6c and are estimated to be substantial, especially for individuals with more years of education. Table 6d reports estimates of the standard errors of the five shocks in the model: the earnings shock, preference shocks for the three schooling types, and a preference shock for staying home. Last, Table 6e reports estimates of the parameters associated with the type probabilities. Recall from the estimated earnings coefficients that type 2 individuals have the highest earnings constant and type 1 individuals have the lowest. An increase in parents' education increases the probability of being type 2. A smaller number of siblings, higher family wealth, and living in Santiago also increase the probability of being type 2.

5.5 *Model goodness-of-fit*

Table 8 presents the goodness-of-fit for the educational attainment distribution for the subsample that was and was not exposed to the voucher program from the beginning of primary school (age 6) and for the subsample not exposed since age 6. To generate this table, we use the estimated model to simulate choices for all the individuals in our sample, starting from their initial conditions, and we compare the simulated and actual education distributions. As seen in the table, the simulation captures the much higher relative educational attainments for the sample that was exposed to the voucher program since age 6. Relative to those students who were not fully exposed, their mean years of schooling is higher, 11.8 years verses 10.7 years in the data and 11.7 verses 10.8 years in the simulation. A comparison of the simulated and actual education distribution reveals that model simulation does a reasonably good job at reproducing the distribution. The percentage of individuals who completed primary education is 68.5% in the data and 72.2% in the simulation for the subsample not fully exposed to the voucher reform in comparison to 84.7% in the data and 84.4% in the simulation for the subsample of people exposed to the reform since age 6. The predicted percentage completing twelfth grade is also fairly accurate for the not exposed subsample. For the exposed since age 6

[36]The actual transfer amount varied during our sample period, but was about $210 per year on an average.

Table 8. Actual and simulated schooling attainment.

	Subsample Not Exposed to Vouchers From Age 6		Subsample Exposed to Vouchers From Age 6	
Years of Schooling	Actual	Simulated	Actual	Simulated
5 or more	94.4	95.9	98.1	98.1
6 or more	94.4	95.9	98.1	98.1
7 or more	87.2	92.0	95.2	96.0
8 or more	87.2	92.0	95.2	96.0
9 or more	68.5	72.2	84.7	84.4
10 or more	63.4	66.9	80.7	80.4
11 or more	54.9	59.5	74.4	74.4
12 or more	50.4	49.1	70.5	64.2
13 or more	22.4	22.4	32.5	30.1
14 or more	19.5	15.1	25.7	20.3
15 or more	14.3	10.1	17.0	13.7
16 or more	9.7	6.3	11.0	8.6
17	4.9	3.3	5.6	4.7

sample, the model accurately predicts the percentage of individuals who finish eleventh grade and start college, but underpredicts somewhat the high school graduation rate. For both subsamples, the simulation underpredicts the percentages of students who drop out of college after 1 year and has a larger fraction going for 2 years. The steeper drop out rates during college predicted by the model may be due to the fact that the model does not incorporate specific types of college degree requirements, which may lead individuals to go to college for additional years. In general, though, the simulation does capture the features of the educational distribution as well as the large observed differences in the distributions for the subsamples that were and were not exposed to the voucher program from an early age.

Tables 9a and 9b report the fit of the estimated model to the primary to secondary school transition for the same two subsamples. In the tables, the simulated unconditional cell percentage appears in parentheses beside the actual percentage. The model simulation replicates the decline in the share of individuals who get an all municipal school education from 50.3% to 45.3% (47.7% to 43.8% in the data) for the subgroup fully exposed to the voucher reform. It also replicates the increase in the share of individuals who get an all subsidized school education from 4.5% to 12.8% (5.5% to 12.7% in the data). The model predicts a large increase in mobility (those who go to a different type of secondary school from primary) for the group exposed to vouchers from age 6 relative to the not exposed group, as seen in the data. For the group that was not exposed to vouchers from age 6, only 13.3% (12.3% in the simulation) attended a secondary school that was different from their primary school, but for the group that was exposed to vouchers from age 6, 23.9% (23.3% in the simulation) attended a secondary school that was different from their primary school. The percentage of the students who stayed in the same type of school also increased from 55.2% to 60.8% (57.3% to 61.2% in the simulations), but the increase for this group (stayers) was proportionately lower

Table 9a. Actual and simulated transition from primary to secondary school subsample not exposed to vouchers from age 6 (2501 individuals; simulated choices in parentheses).

Primary School Type	Stayers (Stay With Same Type of School)	Changers (Change School Type)
Municipal	47.7 (50.3)	8.8 (5.3)
Subsidized	5.5 (4.5)	2.7 (4.0)
Nonsubsidized	2.0 (2.5)	1.8 (2.9)
Total	55.2 (57.3)	13.3 (12.3)

Table 9b. Actual and simulated transition from primary to secondary school subsample exposed to vouchers from age 6 (1409 individuals; simulated choices in parentheses).

Primary School Type	Stayers (Stay With Same Type of School)	Changers (Change School Type)
Municipal	43.9 (45.3)	12.8 (9.6)
Subsidized	12.9 (12.8)	8.9 (10.6)
Nonsubsidized	4.0 (3.0)	2.2 (3.1)
Total	60.8 (61.2)	23.9 (23.3)

than the other group (changers). Thus the share of changers increased from 19.4% to 28.2% (17.7% to 27.6% in simulations).

Table 10 reports evidence on how the model fits labor force participation patterns, disaggregated by type of primary and secondary schools attended. The predicted patterns match general features of the data, such as the higher rates of participation by people who attended municipal primary schools. The predictions are less accurate for those who attended nonsubsidized schools than for the other schooling types, in part because those cell sizes are relatively small. Figure 5 shows the life-cycle employment fit. The model accurately replicates the labor force participation pattern observed in the data, although it slightly overpredicts labor force participation rate in the early part of the life cycle.[37]

Table 11 shows the model fit to mean earnings within cells defined by type of education categories. The mean overall annual earnings predicted by the model is $5012, which is higher than the actual mean of $4901. Disaggregating by school types, the simulated model reproduces the pattern of lower earnings for people who attended only municipal schools or for people who did not attend secondary schools. It also generates the pattern of higher earnings for those who attended nonsubsidized primary and secondary schools, although the simulated earnings in this category understate the actual earnings.

[37]The data exhibit a discrete decline in the labor force participation rates at age 44 (maximum age observed in the data), but that may be due to a data anomaly as there are less 200 observations at that age.

TABLE 10. Actual and simulated labor force participation rates by primary–secondary schooling choice.

	Age 16–45	
	Actual	Simulated
Municipal–municipal	74.3	75.9
Subsidized–municipal	59.5	61.9
Nonsubsidized–municipal	62.8	64.8
Municipal–subsidized	68.4	73.1
Subsidized–subsidized	60.4	66.5
Nonsubsidized–subsidized	61.7	63.6
Municipal–nonsubsidized	64.6	66.1
Subsidized–nonsubsidized	40.2	50.0
Nonsubsidized–nonsubsidized	49.5	57.8
Municipal primary only	87.8	90.7
Subsidized primary only	83.0	83.1
Nonsubsidized primary only	84.4	73.3
All educational categories	75.2	77.0

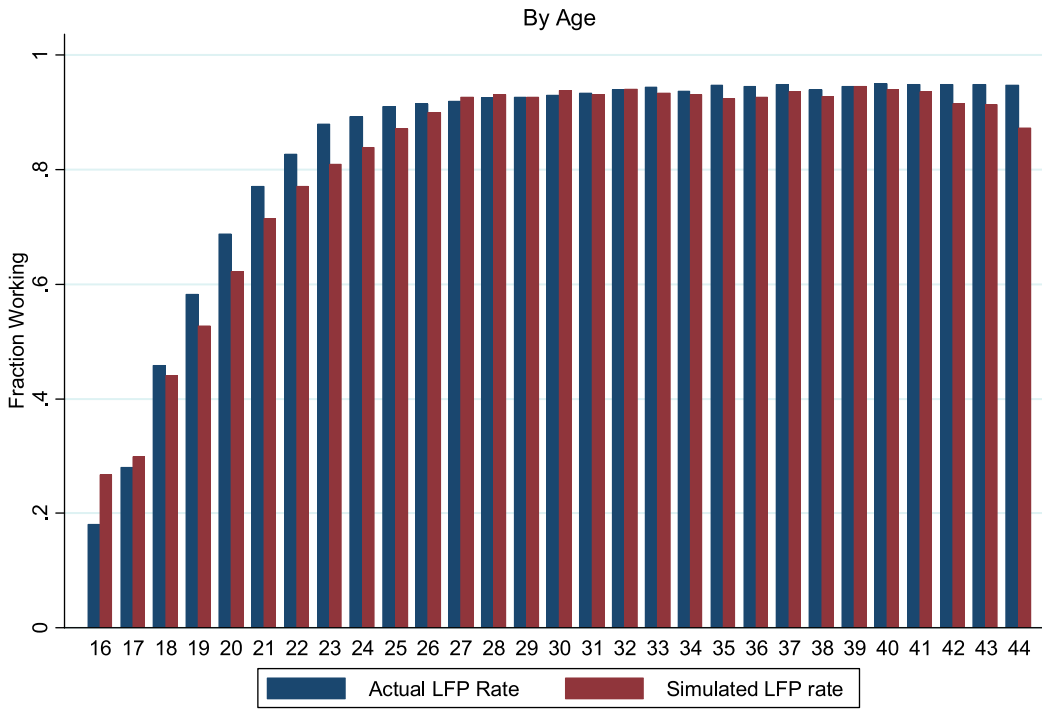

FIGURE 5. Actual and simulated labor force participation rates.

Table 11. Actual and simulated mean wages of workers (in 2002 U.S. dollars) by primary-secondary schooling type and age.

	Age 16–45	
	Actual	Simulated
Municipal–municipal	4982	5347
Subsidized–municipal	5469	5529
Nonsubsidized–municipal	7206	6997
Municipal–subsidized	5970	5478
Subsidized–subsidized	5707	5765
Nonsubsidized–subsidized	3703[a]	6264
Municipal–nonsubsidized	6407	6861
Subsidized–nonsubsidized	6033[a]	5655
Nonsubsidized–nonsubsidized	13,671	7363
Municipal only	3069	3163
Subsidized only	3288	3513
Nonsubsidized only	4287	4353
All educational categories	4901	5012

[a]These cells have relatively small numbers of observations (less than 100).

Figure 6 shows the life-cycle earnings fit. The model mimics the general life-cycle earnings patterns observed in the data, although the model slightly underpredicts average earnings rate in the early part of the life cycle and does not replicate some of the age-by-age fluctuations observed in the data (that are likely due to small samples at some ages).

5.6 *Counterfactual policy evaluation*

We next use the estimated behavioral model to explore how the school voucher reforms affected school attendance and labor market decisions, and whether the reform contributed to declining or increasing inequality in educational attainment and earnings outcomes. To evaluate the impact of the schooling reforms, we simulate school and labor force choices, and earnings outcomes with and without the voucher reform for the group of individuals exposed to the reform over their entire schooling career (from age 6). The simulation without the reform is performed by (i) modifying the budget constraint to reflect the additional tuition cost that would have to be paid for private schooling, (ii) adjusting the returns to schooling to pre-voucher levels, and (iii) adjusting the costs of attending school for all school types to pre-voucher levels. Each person's behavior is simulated 2000 times (i.e., for 2000 sets of draws of the model shocks) and the results reported below are averages from those simulations.

One potential concern in performing these simulations is that there may have been other improvements in the quality of schools in the post-voucher period that also influenced the earnings returns to schooling. Table 12 summarizes the major schooling reforms that took place in Chile since 1980. As it shows, a number of reforms were instituted in 1990 following the reinstatement of the democratic government, most notably

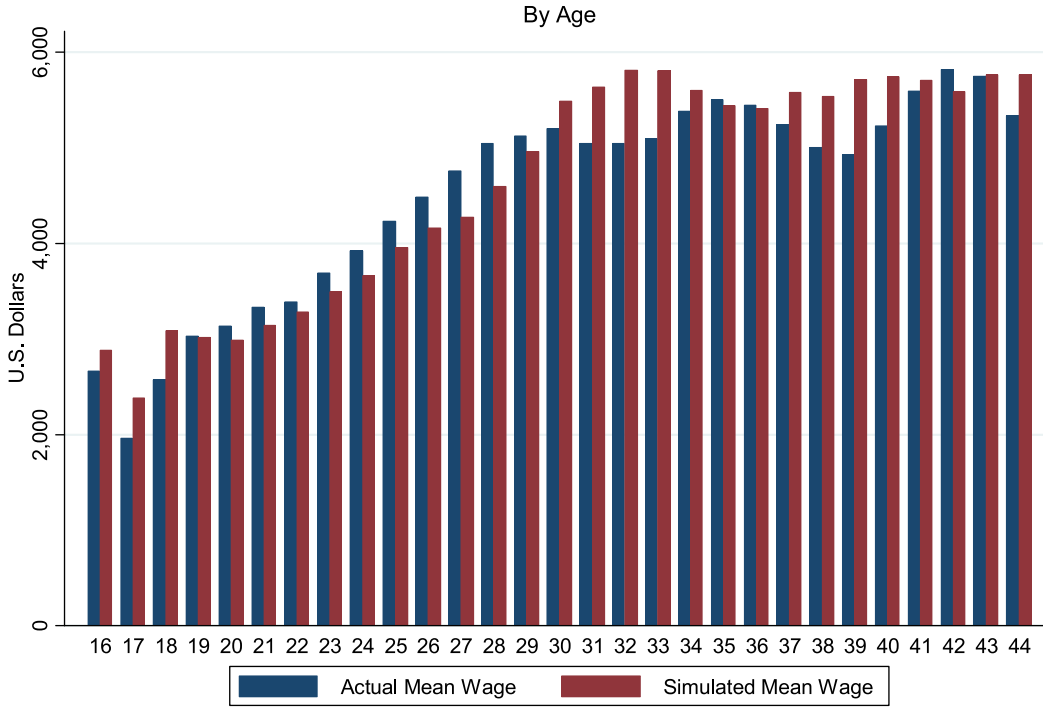

FIGURE 6. Actual and simulated mean wage.

an expansion in the value of the voucher, an increase in school resources (in part implemented through the increase in the value of the voucher), and an almost doubling of the public school teacher earnings that was negotiated by the teacher's union.[38] The change in teachers' earnings is unlikely to dramatically affect the quality of schooling over the short term, because it takes some time to become a licensed teacher and to replace the existing stock of teachers. Over the longer term, however, the higher earnings would be expected to attract more qualified entrants into the teaching profession and improve school quality.[39] In 1994, there was also a change in the voucher rules to allow private voucher schools and municipal high schools to impose a small add-on tuition charge.[40] In later years, some additional schooling reforms were instituted, including a competitive school funding program called SNED (implemented in 1996), an increase

[38]The teacher's union reassumed its role as a bargaining unit after the military regime was replaced by the democratic government in 1990.

[39]There is a college entrance exam given in Chile analogous to the SAT in the United States. The timing of these reforms coincided with a reversal in a long-term declining trend in the average test scores of new teachers, suggesting that the higher pay did increase the quality of new entrants into the teaching profession.

[40]The 1994 law introduced the so-called System of Shared Financing (FICOM). If a school imposes an add-on tuition charge, the voucher amount going to the school is reduced in a way that depends on the level of the tuition charge, but does not fully offset the charge. Over time, the level of the add-on tuition charges (among schools charging any tuition) has gradually crept up, but from the mid-1990s to the start of 2000, the majority of schools imposed either no charge or a relatively small charge.

Table 12. Summary of Major educational reforms in Chile since 1980.

	Reform	Detailed Description
1981	Introduction of nationwide school voucher program	Private subsidized schools have to accept amount of voucher as full payment of tuition. Voucher amount changes somewhat over the years. It decreased in real terms until 1990, when it increased.
1990	Union negotiated increase (almost doubling) of mandatory minimum wage for teachers, applicable for 1990–2004	Both public and private teachers are members of the Teacher's Union, which negotiates over minimum teacher wage applicable to both public and private sector. Teachers in private schools can also form a school level union that negotiates wages over a minimum level, but teachers in public schools cannot. At the end of the 1990s, there was an increase in the entrance exam scores (like SAT) of new teachers, which reversed a previous long-term downward trend in scores.
1990–2004	Increase in school resources	Achieved through increasing voucher amount and through special programs for schools.
1990–Present	P900 Program	Compensatory program that provides additional resources (textbooks, materials, teacher training, not cash) to the 10% lowest achieving schools, based on fourth grade standardized test scores.
	MECE-Rural Program	Compensatory program that provides additional resources to rural schools.
1994	Change in rules to allow public and private schools to impose a small tuition charge on top of the voucher (FICOM)	This was allowed for private subsidized schools and, with some restrictions, for municipal high schools. If they impose a charge, there is a reduction in the voucher amount that does not fully offset the amount of the charge. They also cannot impose the charge on poor families.
1996	Introduction of SNED program—National System of Student Performance Evaluation	Within groups of comparable schools (in terms of student family background), identifies best 25% of schools according to the student results. These schools gain extra funds, which are divided equally between the teachers of the school. Schools are designated "excellence" schools for 2 years.
2000	Increase of 20% in the length of the school day (about 6–7 hours per week) with no change in the number of days per year	This reform required an expansion of many schools, because students had previously attended either morning or afternoon classes, which was no longer possible with the extended school day. Both public and private schools could apply for public school expansion funds and the program was gradually implemented. Information is available on which schools obtained these funds.
2002	Introduction of a new federal teacher certification program	Teachers in public and private subsidized schools voluntarily submit a teaching portfolio (that includes video of classroom time) and take an exam. Teachers who receive the certification get an extra month of pay per year for 10 years, paid for by the government. Currently, about 5% of all teachers receive this certification.
2003	New teacher evaluation program	Mandatory evaluation of all public school teachers every 4 years that can be used for teacher dismissal. Public school teachers are hired at the municipality level.

in the length of the school day along with a school expansion program (implemented in 2000), and the introduction of a new teacher evaluation and certification program in 2002 and 2003.

Most of these reforms come after the individuals in our sample had already completed their schooling. In fact, only 5% of our sample was potentially exposed to the 1996 reform while in primary school and none was exposed to the year 2000 or subsequent reforms. Roughly 15% of our sample was attending secondary school in 1990, so these individuals might have been affected by the 1990 schooling reform that expanded the value of the voucher and increased the teacher earnings or the mid-1990s reform that allowed voucher schools to charge a small add-on tuition. For reasons of parsimony, our model specification does not allow for changes in the return to education for individuals attending in the post-1990 time period for part of their schooling career, although such an extension would potentially be feasible.

5.6.1. *Effects of voucher program on educational outcomes*

Table 13 reports the effect of exposure to the voucher reform on educational outcomes for the subsample of students who were exposed to the reform at any point during their primary and secondary school years. To generate this table, we use the model to simulate behavior with and without the reform in place, over the entire schooling career. To explore distributional effects of the program, we report results for both the whole sample and by whether the individual reports being from a poor family or not, where poor family corresponds to having reported either being indigent or poor when

Table 13. Simulated effect of voucher program on education outcomes by family background status.

	Complete Sample[a]			Poor Subsample[b]			Non-Poor Subsample[c]		
	With Program	Without Program	Diff.	With Program	Without Program	Diff.	With Program	Without Program	Diff.
% Attending private subsidized primary	26.1	17.3	8.8	25.3	16.7	8.6	26.5	17.6	8.9
% Attending private nonsubsidized primary	6.7	9.4	−2.7	6.4	8.9	−2.5	6.9	9.6	−2.7
% Attending private subsidized secondary	22.4	13.0	9.4	21.6	12.3	9.3	22.8	13.2	9.6
% Attending private nonsubsidized secondary	5.7	5.5	0.2	5.3	5.0	0.3	5.7	5.6	0.1
% Attending college	30.1	27.0	3.1	29.1	25.8	3.3	30.9	27.6	3.3
25% quantile years of education	10	10	0	10	10	0	11	10	1
Median years of education	12	12	0	12	12	0	12	12	0
75% years of education	13	13	0	13	13	0	13	13	0

[a]Refers to the sample of individuals exposed to the voucher program at any point in their schooling careers.

[b]Refers to the subsample that reported family background as indigent or poor.

[c]Refers to the subsample that reported family background as good or very good.

Table 14. Voucher impact on education distribution: Percent completing at least x years of schooling.

	Complete Sample[a]			Poor Subsample[b]			Non-Poor Subsample[c]		
Years of Schooling	With Program	Without Program	Diff.	With Program	Without Program	Diff.	With Program	Without Program	Diff.
5	98.1	97.5	0.6	97.9	97.2	0.7	98.2	97.6	0.6
6	98.1	97.5	0.6	97.9	97.2	0.7	98.2	97.6	0.6
7	96.0	95.2	0.8	95.6	94.7	0.9	96.2	95.4	0.8
8	96.0	95.2	0.8	95.6	94.7	0.9	96.2	95.4	0.8
9	84.4	81.4	3.0	83.0	80.0	3.0	85.1	82.2	2.9
10	80.4	77.0	3.4	78.8	75.3	3.5	81.1	77.8	3.3
11	74.4	70.8	3.6	72.6	68.9	3.7	75.3	71.7	3.6
12	64.2	60.6	3.6	62.2	58.6	3.6	65.1	61.6	3.5
13	30.1	27.0	3.1	28.9	25.8	3.1	30.7	27.6	3.1
14	20.3	17.7	2.6	19.5	16.9	2.6	20.8	18.1	2.7
15	13.7	11.4	2.3	13.0	10.8	2.2	14.0	11.6	2.4
16	8.6	6.8	1.8	8.2	6.5	1.7	8.8	7.0	1.8
17	4.7	3.4	1.3	4.4	3.3	1.1	4.8	3.5	1.3

[a]Refers to the sample of individuals exposed to the voucher program at any point in their schooling careers, over ages 15–45.
[b]Refers to the subsample that reported family background as indigent or poor.
[c]Refers to the subsample that reported family background as good or very good.

growing up.[41] As seen in the first row of Table 13, the voucher program increases attendance at private subsidized primary schools by 8.8 percentage points. There is similarly a substantial increase in attendance at subsidized secondary private schools of 9.4 percentage points, which is slightly larger for the non-poor subsample than the poor subsample. The voucher program also modestly increased the attendance rate at nonsubsidized private schools, because it increased school-attendance in general. The simulations indicate that the reforms increased attendance at college by 3.1 percentage points. By reducing high school dropout rates, more people become eligible to go to college.

Table 14 shows how the voucher program affects the entire education distribution for the same three subsamples. There is a shift of the educational attainment distribution to the right, with especially large effects of the reform on the probability of completing 11–13 grades. A comparison of the results for the poor and non-poor subsamples reveals similar impacts by family background. The last four rows of Table 14 show the effects of the voucher program on the college completion rate, which are also positive.

5.6.2. *Impacts on labor market outcomes*

Table 15a examines the effects of the voucher reforms on earnings and labor force participation, by age of worker and by family background (poor or non-poor). To obtain these results, we use the estimated model to simulate schooling and labor participation decisions with and without the voucher reform in place for individuals age 16–45

[41]Family background socioeconomic status was reported in four categories (see Table 1) and we take the first two categories as poor.

Table 15a. Voucher program impact on labor market outcomes (earnings and labor force participation).

	Complete Sample[a]		Poor Subsample[b]		Non-Poor Subsample[c]	
	With Program	Without Program	With Program	Without Program	With Program	Without Program
Earnings of workers						
Ages 16–25	3153	3168	3040	3054	3211	3227
Ages 26–35	4672	4733	4565	4619	4727	4791
Ages 36–45	5258	5263	5129	5129	5324	5331
Ages 16–45	4361	4388	4245	4267	4421	4550
Percent of time participate in the labor force						
Ages 16–25	58.3	60.2	59.6	61.5	57.6	59.5
Ages 26–35	92.8	92.7	93.0	93.0	92.7	92.6
Ages 36–45	93.8	93.5	94.0	93.7	93.7	93.4
Ages 16–45	81.6	82.1	82.2	82.7	81.3	81.8

[a]Refers to the sample of individuals exposed to the voucher program at any point in their schooling careers, over ages 16–45.
[b]Refers to the subsample that reported family background as indigent or poor.
[c]Refers to the subsample that reported family background as good or very good.

Table 15b. Voucher reform impact on the earnings distribution (for working persons).

Percentile	With Reform	Without Reform	Decomposition #1: Only Returns Changed	Decomposition #2: Only Costs Changed
1	1960	1899	1993	1895
5	2491	2438	2426	2513
10	2833	2798	2751	2881
50	4526	4515	4447	4610
90	5794	5914	5787	5914
95	6183	6312	6182	6313
99	6696	6839	6695	6838
Mean	4361	4388	4310	4444
S.D.	1105	1145	1113	1137
90–10 ratio	2.04	2.11	2.10	2.05
50–10 ratio	1.59	1.61	1.61	1.60

who were exposed to vouchers at any point in their schooling career. The column labeled "With Reform" refers to the results obtained using the post-reform estimates of the costs of attending school and of the schooling earnings returns. As seen in the table, the time spent in the labor force decreases with the reform for the younger age groups due to their spending a longer time in school, which delays their labor force entry. For older age workers (36–45), labor force participation increases slightly. Despite the longer school attendance, however, there are almost no effects of the voucher reform on aver-

age earnings. The lack of increase occurs because the earnings benefits from higher levels of education are partly offset at the higher end of the education distribution by the decline in the returns to secondary education (seen in Table 6a).

Table 15b examines how the distribution of earnings was affected by the reforms. The second and third columns report the earnings quantiles obtained from the simulations with and without the reform in place. The results indicate a modest increase in earnings at the bottom percentiles and a decrease at the top percentiles, leading to a modest overall decline in the earnings variance.[42] Also, both the 90–10 ratio and the 50–10 ratio are higher without reform.

This observed decline in inequality potentially comes from two sources: changing returns to education and changing costs of attending school. As previously noted, the returns to primary education increased for both municipal and subsidized primary schools after the reform, which led unambiguously to increased earnings for individuals at the lower end of the earnings distribution. Returns to secondary education declined, which reduced earnings for people in the upper quantiles of the distribution. Both forces tend to compress the earnings distribution. After the reform, the cost of attending school was reduced for two reasons: the voucher eliminated tuition at private subsidized schools and the costs of attending school decreased, particularly in the non-Santiago region, for all types of schools.

We next use a decomposition method to explore the relative importance of changing returns and changing costs in explaining the overall impact of the reform on the earnings distribution. That is, we first simulate the model under the hypothetical scenario that only the returns to schooling changed, but the cost of attending school remained fixed at the estimated pre-reform levels. Then we simulate the model holding returns to schooling fixed at pre-reform levels and allowing only the costs of attending school to change. As seen in the fourth column of Table 15b, changing only the returns to schooling leads to an increase in earnings of about 5% near the bottom of the earnings distribution. The mean earnings overall is lower and the 90–10 and 50–10 ratios very similar compared to the baseline without reform scenario. The simulation that varies only the costs of attending school and holds returns fixed at pre-reform levels indicates a higher mean earnings and a lower 90–10 ratio and 50–10 ratio relative to the without reform scenario. The decomposition analysis shows that the changes in the returns to schooling have a beneficial impact mainly for individuals at the lowest quantiles of the earnings distribution, and decreased costs of attending school benefitted those in the lower-middle and middle of the earnings distribution.

Table 16 examines how the voucher reform affected the distribution of discounted lifetime earnings and discounted lifetime utilities. Comparing average discounted lifetime earnings with and without the reform, we see that average earnings stays nearly the same. Examination of the percentiles again reveals a small decrease in earnings inequality, with increases in discounted lifetime earnings at the bottom percentiles and slight decreases at the top. The utility-based measure takes into account the utility from

[42]Individuals at the bottom of the earnings distribution would tend to have completed only primary schooling, and the returns to primary schooling increased after the voucher reform. Mostly for this reason, earnings increases at the bottom of the distribution.

Table 16. Voucher reform impact on present discounted lifetime earnings and utility.

	Discounted Lifetime Earnings (From Age 16 to Age 45)		Discounted Lifetime Utility (From Age 6 to Age 45)	
Percentile	With Reform	Without Reform	With Reform	Without Reform
1	11,138	10,980	9625	8309
5	11,797	11,663	10,741	9382
10	12,231	12,122	11,430	10,048
50	13,760	13,542	13,049	11,640
90	17,844	18,015	15,870	14,675
95	18,397	18,568	16,507	15,271
99	19,381	19,689	17,625	16,322
Mean	14,679	14,646	13,510	12,217
S.D.	2223	2360	1766	1851
90–10 ratio	1.46	1.49	1.39	1.46
50–10 ratio	1.12	1.12	1.14	1.16

time spent not working and from time spent attending school, both of which are not taken into account by the earnings-based measure. Average discounted lifetime utility increased by a substantial amount (roughly 10%), with large increases (15%) at the lower percentiles of the utility distribution and smaller increases (7%) at the higher percentiles.[43] The results indicate increased lifetime utility at all percentiles.

6. Conclusions

This paper uses a longitudinal data set from Chile to study the longer-term effects of nationwide school voucher and decentralization reforms on educational and labor force outcomes over the life cycle. The previous literature on the voucher reforms in the Chilean context focused on test score impacts using test score data that were collected only after the reforms were introduced. Our study uses household survey data on individuals who obtained their education before, during, and after the voucher reforms, and therefore has the potential to capture reform-related changes in both public and private sector schools.

After estimating a dynamic model of school attendance and work decisions, we use the model to evaluate how the introduction of school vouchers affected school choice, educational attainment, earnings, and labor market participation for the subgroup of people exposed to the vouchers. Simulating schooling and labor supply choices over the life cycle with pre- and post-reform estimated model parameters permits a direct assessment of the effects of the reform as it operates through multiple channels over the life cycle.

[43]The increases in the presented discounted value of utility are relatively large, in part because the benefits of the voucher reform (elimination of tuition at private subsidized schools, higher primary school returns, and lower costs of attending schools) occur early in life and the costs of the reform (lower earnings returns to secondary schooling) occur later in life. Our relatively low estimated discount rate of 0.79 also implies heavy discounting of future utility.

We find that the earnings returns to municipal and to private subsidized primary schooling increased in the post-voucher period, which is consistent with improvements in the quality of primary schooling. At the secondary school level, however, returns to schooling fell relative to pre-voucher levels, which likely reflects that the newer schools that entered the secondary school market after the reform were not as high quality as the more established schools and that per-pupil expenditure declined in the decade following the introduction of vouchers, particularly in secondary schools.

Our model estimates also suggest substantial declines in the costs of attending school in regions outside of Santiago in the post-reform period. The combined effects of (i) decreased costs of attending school, (ii) the tuition voucher, and (iii) changes in the returns to schooling on net induce higher school attendance rates, with a larger fraction of individuals attending private schools. Overall, our model simulations find large effects of the voucher reform on schooling attainment. Specifically, being exposed to the voucher reform over the entire schooling career increases primary school graduation rates by 0.6 percentage points, high school graduation rates by 3.6 percentage points, college attendance rates by 3.1 percentage points, and the 4-years college completion rate by 1.8 percentage points. In addition, the reform reduced labor force participation at ages 16–25 by about 2 percentage points, off a baseline of 58.3%.

With regard to earnings, we find that the reform did not lead to increased overall average earnings, because the earnings benefits of having greater educational attainment are partly offset by the delay in entering the work force and by the post-reform decrease in the returns to secondary schooling. An examination of the earnings distribution, though, shows that earnings increased at lower percentiles of the distribution and decreased at upper percentiles, generating a modest reduction in earnings inequality. The impacts of the voucher reform are similar in magnitude for individuals from both poor and non-poor backgrounds, alleviating concerns that the voucher reforms only benefitted children from wealthier families. An examination of the effects of the voucher reform on discounted lifetime utility indicates a substantial increase of around 10%, on average.

Appendix

The sampling frame of the 2002 HLSS survey consists of individuals enrolled in the social security system for at least 1 month during the 1981–2001 time period, which included individuals who in 2002 were working, unemployed, out of the labor force, receiving pensions, or deceased (in which case the information was collected from surviving relatives). The sample was drawn from a sampling frame of approximately 8.1 million current and former affiliates compiled from official data bases (which cover approximately 75% of the population). The sampling frame for the EPS in 2004 was augmented to include individuals not affiliated with the social security system, so that the sample is representative of the entire Chilean population over the age of 15. Individuals who were interviewed in 2004, but were not interviewed in 2002, were asked questions pertaining to both the 2002 and the 2004 time period. In our analysis, we use the longitudinal data collected by both the 2002 and the 2004 surveys, using weights to reweight the sample back to random sampling proportions.

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