Gender Pension Gaps in a Private Retirement Accounts System: A Dynamic Model of Household Labor Supply and Savings

Clement Joubert and Petra E. Todd *

Abstract

This paper develops and estimates a dynamic model of individuals' and couples' labor supply, savings, and retirement decisions to analyze how the design of Chile's privatized pension system and a reform undertaken in 2008 affect gender pension gaps and old-age poverty. Chile has one of the longest-running private retirements accounts systems in the world, which has served as a model for many countries. The paper estimates the dynamic model using pre-reform data and compares the model's short-term forecasts with reduced form estimates of the reform's causal impacts. The model provides accurate forecasts, so it is used to evaluate how actual and counterfactual changes in the pension system design affect men's and women's labor supply and savings decisions, pension receipts, and program costs over a longer time horizon. The results show that three design features significantly reduce gender pension gaps: expanding minimum pension benefit eligibility, providing a per-child pension bonus, and increasing women's retirement age to be equal to men's. Overall, the 2008 pension reform largely achieved its goals of reducing gender gaps and old age poverty, although the new system costs double that of the old system.

JEL Classification: J240, J260, E210, E260, O170

Keywords: Private pensions, Gender Gaps, Household labor supply, retirement, savings, structural estimation

*Petra E. Todd is the Edmund J. and Louise W. Kahn Term Professor of Economics at the University of Pennsylvania and Clement Joubert is an economist at the World Bank's research group. This research uses data from the EPS survey. We would like to thank Ivan Suvorov for excellent research assistance and the Subsecretaría de Previsión Social of Chile for granting permission to use the data base. The Subsecretaría is not responsible for the results presented in this paper. This paper builds on an initial study that Todd and Joubert did as consultants to the Budget Office in the Chilean government. A preliminary version of the paper was presented at the LACEA meetings in Santiago, Chile, Nov., 2011, at NYU, Washington University-St. Louis, University of Minnesota, and University of Chicago. We would like to thank Alberto Arenas, David Bravo, Santiago Levy, Evelyn Matthei, Beatriz Moraga, Roy Rogers, the Superintendencia de Pensiones and seminar participants for helpful comments. We also are grateful for funding for research assistants from the National Institutes of Health - National Institute on Aging, Grant number P30 AG12836, the Boettner Center for Pensions and Retirement Security at the University of Pennsylvania, and National Institute of Child Health and Development Population Research Infrastructure Program R24 HD-044964, all at the University of Pennsylvania.

1 Introduction

Many traditional pay-as-you-go social security systems face impending insolvency as the number of pensioners per worker rises. The kinds of reforms being considered include, for example, increasing the required contribution per worker, raising the standard retirement age, or completely overhauling the pension system by transiting to a private accounts system. Chile has been at the forefront of pension reform, having switched to a private retirement accounts system in 1980.[1] Many plans proposed in the United States and Europe are similar to Chile's current pension system.[2] They outline a system in which workers are mandated to contribute part of their income to a pension account that is managed by a money manager, either a government owned company or a private firm. Under the proposed plans and also under the Chilean system, the government serves as a last resort guarantor, supplementing pension income if pension accumulations are insufficient, either due to low income or unfavorable investment returns.

A potential drawback of a private retirement accounts-based system is that it can leave women particularly vulnerable to old-age poverty. This is because women typically experience lower wages, careers interrupted by child bearing, and longer life spans.[3] In 2008, Chile undertook a major reform of its pension system largely out of concerns about old age poverty and gender gaps in pension accumulations and pension receipt. The reform incorporated more generous noncontributory pension benefits into the pension system design, and other features likely to benefit women such as a pension supplement for each child born and pension fund transfers between divorcing spouses. However, policy makers have been concerned that these changes may reduce working and savings incentives for both men and women.

This study develops and estimates a dynamic structural model to examine how pension system design affects gender gaps in pensions and household labor supply and savings decisions over the life-cycle. The households, which can be either couples or individuals, make choices over time with regard to labor supply, private savings and retirement in an environment with uncertainty about future wages, returns on pension savings, fertility, divorce or widowhood and own survival. Men

[1] The Chilean pension fund system is known as the *Administradoras de Fondos de Pensiones* or *AFP* system.

[2] In the U.S., President G.W.Bush in 2005 and Republican Party presidential primary candidate Herman Cain in 2011 invoked the Chilean model as a blueprint to reform Social Security. Chile's system served as a model for pension reform in many other countries (dates of adoption in parentheses), including Peru (1993), Argentina (1994), Colombia (1994), Uruguay (1995), Bolivia (1996), Mexico (1997), El Salvador (1998), Costa Rica (2000), Czech Republic (1994), Hungary(1998), Poland (1999), Bulgaria (2000), Estonia (2002), and Kazakhstan (1998).

[3] See Bertranou (2001), James et al.(2003), and Fajnzylber (2012)

and women choose both labor supply and whether to work in the formal sector, where pension contributions are mandatory, or in the informal sector. Individuals always receive an informal sector wage offer and also receive a formal sector offer with positive probability depending on their characteristics. They choose the sector to maximize their present discounted expected utility, in the tradition of a Roy model.(Heckman and Honore (1990), Keane and Wolpin (1997)) The distinction between formal and informal sector work is important in Chile (and in many countries across the world), because many individuals work in the informal sector and reach old age having contributed little to the pension system. The model is estimated using longitudinal microdata from the *Encuesta de Protección Social (EPS)* merged with administrative data on pension funds.[4]

We use the estimated model to study how labor supply and savings behavior changes with the introduction of the 2008 pension reform in comparison to the previous pension system and in comparison to alternative pension system designs. We estimate model parameters by the method of simulated moments using pre-reform data from the 2004 and 2006 EPS Surveys. The estimation results reveal substantial heterogeneity in how individuals value pecuniary and non-pecuniary dimensions of formal and informal work. Some individuals have strong comparative advantages to working in the formal or informal sectors, which dampens behavioral responses to pension system changes.

Incorporating the pension rules explicitly in our model allows us to construct counterfactual simulations in which the reform did not happen, keeping everything else constant. In this way, we perform an ex ante prediction of the short-run behavioral impacts of the pension reform and compare our predictions to evidence from other causal impact studies of the reform's impacts. Consistent with other studies, we find that a more generous safety net induces wealth effects that lead older men and women to retire earlier. At younger ages, however, some men increase their labor force participation, which we attribute to the pension reform's relaxation of the stringent means test that was used to determine minimum pension benefit eligibility under the old pension system. Our simulations also show that marital status is an important determinant of pension policy reform responses. Even though many of the reform features were targeted at women, men's responses are sometimes greater than those of women, as men respond to the wealth effect of the increase in their wives' pension benefits. We do not observe any crowding-out of private savings.

[4]The longitudinal household survey data were collected by the Microdata Center under the supervision of David Bravo and the administrative data come from Chile's *Superintendencia de Pensiones*.

We then use the model to perform simulations over longer time horizons to analyze the effects of actual and counterfactual pension program designs on a range of outcomes including pension gender gaps, labor force participation rates, years of pension contributions, benefit receipt levels and household assets. We focus on design features that have been proposed by policy-makers as possible ways of reducing gender gaps, such as, requiring individuals to make pension contributions to their spouse's account in years when their spouse does not work or increasing the mandatory retirement age of women to match that of men. We predict the effects of the actual pension reform and of alternative scenarios by simulating our sample households' decision-making over a 20-year time horizon. We also report the government cost of various alternatives.

The results indicate that pension system design changes introduced with Chile's 2008 pension reform dramatically improve pension saving and receipt levels for women, bridging a sizable part of the male-female pension benefit gap. The gender pension gap reduction is attributable mainly to the expansion in eligibility for a minimum pension guarantee, the so-called basic solidarity pension (*Pensión Básica Solidaria*, or PBS) and from an increase in the generosity of the minimum pension benefit.[5] The work requirements for receiving the minimum pension benefit guarantee were also removed through the reform. The per-child bonus also emerges as an important feature that increases women's pensions relative to men's, particularly for less educated women who tend to have more children and participate less in formal sector work. Raising the retirement age of women does not result in an increase in years contributed but does significantly increase female pension benefits, by reducing their expected longevity at retirement and allowing pension funds to accrue interest longer.

The paper proceeds as follows. Section 2 discusses the related literature on modeling behavioral effects of social security and pension rules. Section 3 gives some background on the Chilean pension system and the 2008 pension reform. Section 4 describes the model and section 5 summarizes the data used in estimation. Section 6 discusses parameter estimates, provides evidence on within-sample model fit, and compares the model's predicted short-run impacts with the available post-reform reduced form evidence. Section 7 uses the model to analyze how different pension system design features, some of which were not included in the reform, impact gender equity and household decisions. Section 8 concludes.

[5]The Chilean pension system and the 2008 reform are described in detail in section 3

2 Related literature

This study builds on a literature, pioneered by Fields and Mitchell (1984) and Mitchell and Fields (1984), that models how the structure of earnings, social security, and pension benefits affect retirement behavior. Their model assumed that individuals make a one time retirement age decision, taking into account future expected earnings and retirement benefits. They found that wealthier individuals retire earlier, and those who expect to gain more by postponing retirement retire later. Subsequent research developed and implemented fully dynamic modeling approaches that incorporate uncertainty in decision-making over time. An early dynamic model by Gustman and Steinmeier (1986) showed how pension benefits affect the lifetime budget constraint and alter the price of leisure at different ages, thus influencing the choice of retirement age. Stock and Wise (1990) analyzed the effect of pension plan provisions on the retirement age and also emphasized the importance of modeling uncertainty to capture the option value embedded in the retirement decision. Berkovec and Stern (1991) estimated the first dynamic discrete choice model of individual retirement decisions using a dynamic programming set-up. Subsequent papers additionally incorporated into the basic dynamic discrete choice modeling framework other aspects, such as health expenditure risk, savings and detailed institutional pension rules to provide a fuller accounting of retirement determinants.[6]

The more recent literature estimates dynamic structural models of husbands' and wives joint retirement decisions. Our modeling framework is most closely related to that of Van der Klaauw and Wolpin (2008) who study how the design of U.S. social security rules affects decision-making within a collective household model. As in their model, we allow households to accumulate private savings in addition to pension benefits for consumption in retirement. One important difference is that we focus on gender aspects of pension design and incorporate divorce and separation in our model. These events are major financial risks for women with low private and pension savings and low labor force attachment. We do not incorporate health or health insurance, in part because Chile has a public health insurance program. Also, we allow only women and not men to work part-time. Another difference is that our model allows workers to make a choice about being employed in the informal sector, in which they do not contribute to their pensions or make progress towards qualifying for a minimum pension. This is a crucial margin from a public finance point of view in

[6] See, e.g., Rust and Phelan (1997), French (2005), Blau and Gilleskie (2008), French and Jones (2011) and Blundell et al. (2016) for a survey.

Chile and many other countries around the world.

Other recent collective models of joint retirement include Blau and Gilleskie (2006), who focus on retirement incentives related to spousal health benefits, and Casanova (2010), who investigates the timing of retirement between two married individuals. Because these papers are not concerned with the difference in financial risk borne by each spouse individually, they model divorce and death through a terminal value, instead of following, as we do, individuals after separation or death has dissolved the household.[7] Many individuals, especially women, spend a significant part of their retirement as widows, so following them after their spouse dies is important to understanding old age poverty.

Another related line of research examines how marriage-related features of the US tax system and social security system affect household labor supply, savings and welfare, either with calibrated or estimated dynamic models. For example, Kaygusuz (2015) uses a general equilibrium, life-cycle model to quantify the redistributive, labor supply and welfare implications of US social security policies. Keeping the pay-as-you-go system in tact, he examines the implications of removing spousal benefits, the survival benefit, and the social security earnings cap and finds a large effect (5.5% increase) on the labor force participation of married females. Groneck and Wallenius (2017) develop a structural life-cycle model of singles and couples with uncertain marital states and survival that they use to examine labor supply effects and distributional consequences of the US social security system. Their study also finds that auxiliary benefits (benefits linked to marital status) have a large negative effect (12.2pp) on married women's employment. They use the model to find a revenue neutral minimum benefit scheme that would reduce inequality relative to the current system. Another paper by Sánchez-Marcos and Bethencourt (2018) assesses the impact of spousal and survivor pensions using a life-cycle model in which households decide on female labor supply and savings, and they find that removing spousal and survivor pensions increase female labor supply. In addition, they use the model to analyze effects of changing the formula used to calculate worker pension levels (to include more working years, from 35 to 40) and to analyze the implications of pension design changes for income and consumption inequality. A recent paper by Borella, De Nardi and Yang (2021) develops and estimates a structural model of couples' and singles that incorporates

[7]Other notable papers are Gustman and Steinmeier (2000, 2002) who consider a non-cooperative game solution to the household joint decision, and Gallipoli and Turner (2011) who compare non-cooperative and collective models of joint retirement. In the macroeconomic literature, Nakajima (2011) calibrates an equilibrium collective model of joint retirement, focusing on spousal and survivor benefit policies.

participation and hours decisions of both men and women as well as savings decisions. They study the implications of joint income taxation and social security spousal and survivor benefits using data from two birth cohorts (1941-45 and 1951-55). They find that removing marriage-related tax and social security provisions leads to an increase in labor force participation for women over the life-cycle and a decrease in labor force participation for men starting at age 60. It also leads to a significant increase in savings, 20% by age 66. In addition, their model simulations show that eliminating these provisions would increase welfare for the vast majority of couples and singles.

This paper also builds on a previous study by Joubert (2015) of the relationship between pension design and labor force participation decisions with regard to informal/formal sector work using the same data as we use. We extend Joubert (2015) by using a collective household model and by allowing for divorce and fertility, which make the model suitable for studying the differential impact of the 2008 pension reform on men and women.

Lastly, this study is broadly related to a literature initiated by Auerbach and Kotlikoff (1987) that examines the welfare effects of pension reform using life cycle and overlapping generations models.[8] Three recent related papers in that strand are O'Dea (2018) who computes the optimal level of means-tested non-contributory pensions, McKiernan (2018) who models the Chilean transition from pay-as-you-go to a privatized pension system, and Nishiyama (2018) who analyzes the effects of spousal and survivors benefits on the labor supply of married women and on the output of the overall economy.

3 Background on the Chilean pension system and the 2008 reform

When it was introduced in 1980, the privatized Chilean pension system, called the AFP system, replaced a heterogeneous pay-as-you-go system composed of many different institutions (called *Cajas de Prevision*) that covered different professions and subpopulations.[9] Individuals in the old pension system (now known as the INP system) had the option of transferring to the new AFP system based on individual capitalization or remaining in the old system.[10] To encourage transfers, workers who opted for the new system received a 12.6 percent increase in net income (the new contribution rate plus commissions or fees) and the benefits accrued under the old system were

[8] A partial list of notable papers in this branch of the literature includes Conesa and Krueger (1999), Kotlikoff et al. (1999), Huggett and Ventura (1999), Nishiyama and Smetters (2007)

[9] AFP =*Administradoras de Fondos de Pensiones*

[10] INP= *Instituto de Normalizacion Previsional*

recognized through the issuing of a "recognition bond," payable upon retirement. Labor force entrants after 1980 were required to affiliate to the new system.[11] By the end of 1983, 77 percent of workers from the old system had switched to the new one (Acuña and Iglesias (2001)).

The AFP system is a savings program based on defined-contribution individual accounts. The program is mandatory for salaried workers and voluntary for self-employed. Affiliated workers pay 10 percent of their monthly wages (up to a cap) into a tax-deferred pension account, which is for the most part inaccessible until retirement.[12] A pension system affiliate can choose to invest his/her pension funds in one of a number of pension fund administrators (the AFP firms) who manage and invest the savings in the financial markets.

Individuals can access their pension savings at age 65 for men and 60 for women, with three withdrawal options: Programmed Withdrawals (*Retiro Programado*), purchase an annuity from an insurance company (*Renta Vitalicia*), or a mix of phased withdrawals for a period of time and a deferred lifetime annuity. The law also allows for early retirement, provided that the worker has pension funds sufficient to generate a pension amount equal to or greater than 110 percent of the minimum pension guaranteed by the state.[13]

Prior to the 2008 pension reform, the state provided noncontributory retirement income transfers through two mechanisms. First, a welfare or assistance pension, known as the *PASIS* pension, equal to a little less than a third of the minimum wage was available for program applicants above 65 years of age, irrespective of contribution history, and was allocated based on an index of economic vulnerability, called "ficha CAS".[14] The second transfer was a minimum pension guarantee (MPG) equal to about twice the PASIS pension. Individuals with more than 20 years of contributions received the MPG if their accumulated contributions could not finance a higher pension. Both of these benefits took the form of a top-up, that is, the benefit was equal to the difference between the guaranteed level and the pension financed by the worker's account.

[11] Government and military workers are exempted and have separate pension systems.

[12] The restrictions on fund withdrawal are more stringent in Chile than they are for US 401K plans. The contributions are capped at 60 Unidades de Fomento, a monetary unit that is indexed to inflation. The value of the UF as of December 2004 was $17,317 pesos (US$31). In addition, workers must pay a contribution of 7 percent for health services, 0.8 percent for a disability and survivorship insurance, and an average of 2.6 percent to the pension fund manager as a commission or fee.

[13] The pension must also be equal to or greater than 50 percent of the average taxable income for the last 10 working years.

[14] In August 2007, the minimum wage was 159,000 pesos per month, while the PASIS was 44,186 pesos for retirees between 65 and 70 years of age, 47,103 pesos between 70 and 75 and 51,503 pesos if older than 75.

3.1 Gender pension gaps and the 2008 reform

The pension system underwent significant reforms in 2008 aimed at alleviating old age poverty and reducing gender gaps in pension accumulations. A micro-level analysis of pension contribution histories (Arenas de Mesa et. al. (2007)) showed that most individuals were expected to have low pension accumulations upon retirement.[15] Only 37 percent of women were projected to have a pension above the MPG level in comparison with 67 percent for men. The average projected replacement rate for women under the pre-reform pension system was 28 percent of the last wage in comparison to 51 percent for men.

An important factor underlying gender gaps in projected pensions is that labor force participation is lower and more sporadic among women. Arenas de Mesa and Montecinos (1999) note that the direct link between lifetime earnings and pensions in the AFP system largely accounts for the lower average pensions for women, who tend to retire at earlier ages, participate less often in the labor-force and earn lower salaries. A statistic that is sometimes used as a measure of pension program participation is the *density of contributions*, which is the number of years the individual makes pension contributions divided by the number of potential working-age years. The density of contribution for women is 41 percent in comparison with 61 percent for men. Additionally, women tend to receive lower wages, which further reduces the rate of accumulation of pension savings.

A second consideration is that pension system rules are themselves not gender-neutral. As mentioned above, women are allowed to claim pension benefits at age 60, or 5 years earlier than men. In addition, the life tables used to compute programmed withdrawals and annuity pay-outs reflect the longer life-spans of women. Both factors result in lower pensions for women relative to men. Note that if we consider pension wealth, measured by the present discounted value of pension benefits at the time of claiming, these gaps in pension benefits are compensated by the larger number of years in which women receive them. This study focuses on pension income as the main outcome of interest, largely because the Chilean government, and policy makers more generally, use this outcome as determinant of a pensioner's well-being. Section 7 isolates pension income gaps that are related to asymmetries in the number of years of pension receipts. These gaps may not be associated with lower pension wealth and may for that reason have different normative implications from those related to differences in labor market outcomes.

[15] The micro-level data on pension contribution histories were obtained from a database of the pension fund regulatory agency, the *Superintendency of Pensions* or SP. These are the same data as used in this paper.

3.2 The new safety net

Reducing the gender gap in pension benefits/accumulations was a significant objective of the 2008 pension reform. The reform replaced the PASIS pension and the minimum pension guarantee (MPG) with a so-called "New Solidarity Pillar" that augments pension levels of workers with few years of contributions. The new safety net implements a means-tested welfare pension, which guarantees to individuals in the 60 percent least affluent households a pension of 75,000 pesos per month (called *Pension Basica Solidaria*), or PBS.[16] The PBS represents an increase of nearly 50 percent with respect to the former PASIS pension. In addition to providing a minimum pension level, the new system augments low contributory pensions through the Solidarity Pension Supplement or APS.[17] The APS benefit corresponds to a fraction of the PBS that is gradually reduced for workers with relatively larger contributory pensions according to the formula:[18]

$$\begin{aligned} APS &= PBS * \left[1 - \frac{Contributory\ Pension}{Maximum\ Supplemented\ Pension}\right] \\ &= PBS - Contributory\ Pension * CBR, \end{aligned}$$

where CBR is the "claw-back rate" or taper rate, which is equal to the ratio of the the PBS to the Maximum Suplemented Pension. In effect, this means that the APS tapers off at a rate that reached 0.294 (75,000255,000)in July 2011. For example, a worker who can finance a pension of one 100,000 pesos per month with the funds accumulated in his/her individual account will receive a supplement equal to $75,000 - (100,000 * 0.294) = 45,600$. His/her total pension will then be 145,600 pesos per month.[19] James et al. (2003) note that state-financed minimum pension benefits that are targeted toward low earners often benefit women.

Figure 1 graphically shows the effect of the pension reform on the pension level that people qualify for as a function of the total number of years in which they made pension contributions. The two vertical lines show the PASIS pension benefit and also the minimum pension guarantee available to those with 20 years of contributions under the pre-reform system. The diagonal line

[16] This feature was introduced gradually over July 2008-July 2011. The level of the PBS was initially 60,000 pesos and reached 75,000 pesos in July 2009. The coverage of the PBS was started at 40 percent with eligibility being based on an existing poverty index, the Social Protection Index (*Ficha de Proteccion Social)*. After September, 2009, eligibility was based on the household's income.

[17] Aporte Previsional Solidario

[18] The Maximum Supplemented Pension (PMAS or *Pension Maxima con Aporte Solidario*) was gradually increased through the phased implementation from 70,000 pesos per month to 255,000 pesos per month in July 2011

[19] Before the reform, eligible workers effectively faced an implicit marginal tax rate of 100 percent on contributions over some range, in that additional contributions would not increase the level of pension upon retirement. The new pension system design ensures that additional contributions always increase the level of the retirement pension.

that intersects with (0,0) shows the pension benefit financed with the accumulated pension savings. The diagonal line that intersects with the y axis represents the pension amounts under the reformed system.

3.3 Other reform features

A second important feature of the 2008 pension reform with regard to gender equity is the introduction of a pension subsidy for mothers that depends on their number of children. The subsidy seeks to compensate for contribution history interruptions due to pregnancy and infant care. The subsidy level retroactively accounts for children born before the reform. When a woman turns 65, the state augments her pension savings with a benefit equal to a year and a half of pension contributions at the minimum wage (about 280,000 pesos in 2008), plus interest accrued since the child's birth minus commissions paid to the pension fund administrator. A third feature of the pension reform is a change in the rules for dividing pension balances in the case of divorce or annulment. Before the reform, an individual would lose access to their spouse's pension upon divorce.[20] A judge can now rule that up to 50 percent of a spouse's pension balance be transferred to the other spouse's account after a divorce or annulment as a form of alimony. A fourth feature is a change in the premium for disability and survivorship benefits. Prior to 2008, women and men both paid about 1 percent of their wages towards disability and survivorship benefits, which is actuarially unfair to women. As of July 2009, men and women pay contributions that correspond to men's premium, but the premium difference is added back to a woman's pension account. Lastly, the pension reform also made it possible for someone who is not working (for example a stay-at-home mother) to make pension contributions. The contributions can be deducted from the taxable income of a third party, such as a spouse, who can contribute towards the voluntary affiliate's account.

4 A dynamic model of household labor supply and savings

The dynamic behavioral model that we develop and estimate describes how households make work and savings decisions over their lifetime. The model does not have an analytic solution and is therefore solved numerically by backwards recursion. Details of the solution method are provided in appendix A.1.

[20] However, divorce only became legal in Chile in 2004.

In the model, a household may consist of either a couple or a single individual. In each period, couples face an exogenous probability of separation (described below) or of one member of the couple dying, in which case the couples' problem changes to that of a single-headed household. It is important to recognize the existence of permanent unobservable sources of heterogeneity affecting decision-making, so the model incorporates unobserved discrete types (see, e.g, Heckman and Singer (1984) and Keane and Wolpin (1997)) that index couples. Individuals are indexed by the type of couple they form (if married) or would be part of (if single).[21]

4.1 Timing and initial conditions

The superscript $j \in \{m, f\}$ denotes gender, and the superscript c denotes a couple.[22] Periods in the singles' problem are indexed by the individual's age ($t = a_t^j$), while the couples' problem is indexed by the age of the female ($t = a_t^f$). For singles, the decision problem begins at age $t_0 = 35$.[23] For couples, the decision problem begins when the wife turns t_0. Thus, the age of the husband in the first period, $a_{t_0}^m$ is part of the initial conditions. Any household assets (A_{t_0}) or work experience ($X_{t_0}^m, X_{t_0}^f$) accumulated prior to the first model period, as well as any children born prior to female age t_0 (N_{t_0}) are also taken as initial conditions. The initial conditions also include pension savings ($B_{t_0}^m, B_{t_0}^f$), which include any pension rights accumulated by the two spouses under the earlier INP retirement system prior to age $a_{t_0}^j$ ("Bonos de reconocimiento") or under the new AFP system. Finally, the initial conditions include completed schooling levels of men and women (e^j) and their birth cohorts (bc^j). We denote the set of initial conditions for a single household by:

$$\Omega_{t_0}^j = \{A_{t_0}^j, B_{t_0}^j, X_{t_0}^j, N_{t_0}; e^j, bc^j\}.$$

The set of initial conditions for a couple is:

$$\Omega_{t_0}^c = \left[\Omega_{t_0}^m \cup \Omega_{t_0}^f, a_{t_0}^m\right].$$

At ages $t_C^f = 60$ and $t_C^m = 65$ years old (or sooner if they qualify for early retirement), males and females begin to withdraw money from their pension savings accounts. For tractability, we did

[21] In the empirical work, we incorporate four unobserved types. The number of types we could allow was limited due to the model's computational complexity. The type probability is modeled as a logit function of schooling, marital status and birth cohort. Parameter estimates are presented in Table B6

[22] We use the terms husband and wife, but the model applies to cohabiting, non-married couples

[23] Singles are assumed to remain single after age t_0. Married couples are able to transition to being divorced or widowed, as further described below. We estimate the model for singles on people who remain single after age t_0.

not incorporate the choice about whether to take retirement savings as an annuity or as a phased withdrawal. We assume phased withdrawal, because the formula is a simple function of age.[24] The pension benefit levels are calculated according to the rules of the pension system in place, including the minimum pension guaranty (MPG) in the years when applicable. After age 65, either spouse may receive the government pension transfers (PASIS, PBS, APS) for which they qualify, given their individual and family incomes, and according to the rules at that time (pre-reform until 2008, phased implementation of the reform from 2009 to 2011, post-reform after 2011).

By age t_R=75, it is assumed that all individuals who have not yet retired stop working and take leisure for all remaining periods.[25] The last model period is age $t_D = 90$. When both spouses turn t_R, the model assumes that households run down their accumulated savings by optimally consuming until they die or reach the last period. We assume that bequests (savings left after death of both spouses) are involuntary and do not generate utility.

4.2 Decisions

In each model period prior to t_R, a two-person household makes a saving decision (s_t), a labor force participation decision for each individual (d_t^m, d_t^f) and a part-time work decision for the woman (p_t^f), until age t_R. The income that is not saved is split evenly into the two spouses' consumption levels c_t^m, c_t^f. s_t is the fraction of income that is saved and not consumed in period t. The three employment options available to both men and women are to work in the formal sector ($d_t^j = F$), to work in the informal sector ($d_t^j = I$), or to engage in home production ($d_t^j = H$) for $j \in \{m, f\}$. In addition, female workers choose to work part-time ($p_t^f = 1$) or full-time ($p_f^j = 0$).[26] A one-person household makes the same saving and work decisions relevant to his/her gender, but consumes the full amount of income minus savings.

[24] In computing the programmed withdrawals, we used the life tables RV-2004 published by the *Superintendencia de Pensiones*. The 2009, 2010 and 2011 rates of return were used for the corresponding years. To discount years more than 20 years in the future, the 20th discount rate was repeated. For years after 2011, the 2011 vector was used. For years before 2009, a single discount rate of 5 percent was used. If a couple qualifies for the PASIS pension, our simulation assigns the PASIS pension to the woman (only one member of the household can get the PASIS).

[25] This assumption reduces computational complexity by reducing the number of choices needed to be evaluated each decision period.

[26] In the model, part-time work is only an option for females so we set $p_t^m = 0$. In the data, part-time work, defined as working fewer than 31 hours per week is relatively marginal for men (5.6 percent of working men at 35, 10.3 percent at age 60), and is likely to be related to disability, which is not modeled. In contrast, the fraction among women is two to three times as high (14.2 percent at 35, 23.5 percent at 60) and might be related to household joint decisions that are relevant to our model.

4.3 Preferences

Individuals derive utility from consumption and leisure, if not working or working part-time. The utility of leisure is allowed to depend on unobserved type, k. Other variables that affect utility are grouped in $S_t^j = \left[c_t^j, d_t^j, d_{t-1}^j, p_t^j, N_t, \epsilon_t^j\right]$ for $j \in \{m, f\}$, where ϵ_t^j are utility and preference shocks. We denote the union of S_t^m and S_t^f by S_t^c.

The per period utility function of a couple is the weighted sum of the utility of a single male and the utility of a single female, where the weights represent bargaining power (the weight is set to 0.5 in the simulations reported below):

$$u^c(S_t^c; k) = \theta u^m(S_t^m; k) + (1-\theta) u^f(S_t^f; k),$$

The terms $u^m(.)$ and $u^f(.)$ represent the utility from consumption, leisure, and number of children for a single household formed by a male and a female respectively.

The leisure preference shocks are assumed to be jointly distributed normally and to be uncorrelated over time (conditional on the unobserved types):

$$(\epsilon_t^m, \epsilon_t^f) \sim iidN(0, \Sigma)$$

The period utility function is specified below. Indicator variables for participation in sector $s \in \{F, I, H\}$ (formal, informal and home) are defined as: $d_{s,t}^j = I\left(d_t^j = s\right)$, where $I(.)$ denotes the indicator function.

$$\begin{aligned} u^j(S_t^j; k) &= \left(\frac{c_t^j}{1-\eta}\right)^{1-\eta} \left(1 + \exp\left[\nu_0^j N_t + \nu_1^j d_{H,t}^j\right]\right) \\ &+ [d_{H,t}^j + \delta_p^j p_t^j] \cdot \exp\left(\delta_{lk}^j + \delta_n^j N_t + \delta_m^j m_t + \delta_C^j I_{\left(a_t^j > t_C^j\right)} + \epsilon_t^j\right) \\ &+ \phi_{I,k}^j \cdot d_{I,t}^j \\ &+ \phi_s^j \cdot \left(d_{F,t}^j d_{I,t-1}^j + d_{I,t}^j d_{F,t-1}^j\right) \\ &+ \phi_r^j \cdot \left(d_{F,t}^j d_{H,t-1}^j + d_{I,t}^j d_{H,t-1}^j\right) \end{aligned}$$

This formulation allows the marginal utility of consumption to depend on the number of children and on labor market participation. The utility from not being employed is stochastic, type-specific and depends on the number of children (N_t) and marital status (m_t).[27] We allow the utility of

[27] To reduce the number of parameters to estimate, we set the coefficients on the number of children and marital status to 0 in the case of men because these factors have a smaller impact on men's labor force participation in Chile.

leisure to change after the pension system's retirement age (t_C^j), which could capture social norm effects on the supply and/or demand for labor. δ_p^j captures the fraction of the utility of leisure received if employed part-time (an option only for women). Non-pecuniary benefits (or penalties) associated with the informal sector are captured by $\phi_{I,k}^j$, and the costs of switching sectors and entering (or re-entering) the labor force are denoted by ϕ_s^j and ϕ_r^j respectively.

4.4 Household income

The labor market consists of two sectors, a formal sector where paying income taxes and pension contributions are mandatory, and an informal sector. Each working age individual (whether part of a couple or single) receives an earnings offer from the informal sector in every period with probability one. In addition, with a probability Γ_t^j, individuals may receive an offer from the formal sector. The probability depends on his/her gender, level of schooling, age, and whether employed in the formal sector in the previous period.

$$\Gamma_t^j(d_{F,t-1}^j, e^j, a_t^j) = \left[1 + exp^{-\gamma_0^j - \gamma_1^j d_{F,t-1}^j - \gamma_2^j e^j - \gamma_3^j a_t^j}\right]^{-1}$$

The log-earnings offers (for gender $j \in \{m, f\}$, in sector $s \in \{F, I\}$ of type $k \in \{1..K\}$ and with completed schooling levels e^j) are:

$$lnw_{s,t}^j\left(e^j, X_t^j, k\right) = \theta_{0sk}^j + \theta_{1s}^j e^j + \theta_{2s}^j \left(e^j\right)^2 + \theta_{3s}^j X_t^j + \theta_{4s}^j \left(X_t^j\right)^2 + \epsilon_{s,t}^j$$

where θ_{0sk}^j is a gender-, sector-, type-specific constant, θ_{1es}^j a gender-, sector-, schooling-specific cohort effect, θ_{2s}^j the sector-specific returns to schooling, and θ_{3es}^j and θ_{4es}^j the sector- and schooling-specific returns to experience. $\epsilon_{s,t}^j$ are i.i.d. sector-specific earnings offer shocks that are uncorrelated across time-periods and across members of the same household. The earnings offer specification allows returns to experience to differ in both sectors.

The total household disposable labor income of a couple, y_t^c, is the sum of accepted earnings offers, net of income taxes and mandatory pension contributions:

$$y_t^c = \sum_{j \in \{m,f\}} \frac{(1-\tau) w_{F,t}^j d_{Ft}^j + w_{I,t}^j d_{I,t}^j}{1 + p_t^j} - T(A_t, w_{F,t}^m, w_{F,t}^f, d_t^m, d_t^f, p_t^f)$$

where τ is the pension contribution rate. Household income for a single household, y_t^j, is defined similarly.

Formal labor earnings net of pension contributions and private savings returns are subject to a progressive income tax. Taxes due at period t are denoted by $T(A_t, w_{F,t}^m, w_{F,t}^f, d_t^m, d_t^f)$, and depend on the household's stock of private savings, formal sector earnings offers and labor force participation decisions.Net borrowing and borrowing against pension savings are not allowed. It is assumed that individuals working in the informal sector do not pay taxes on their labor income.

4.5 Separation and mortality

In each period, the probability of the man or woman (whether in a couple or single) surviving to the next period, $\pi^{sj} = \pi^{sj}(a_t)$, is assumed to be exogenous.[28] Widows inherit a portion of their former spouse's pension funds to finance a survivorship pension. Household separation (for reasons other than widowhood) is also modeled as an exogenous event. Conditional on both spouses surviving, the probability of becoming separated in period t is assumed to depend on the man's level of education (e^m), and the spouses ages (a_t^m, a_t^f). Until 2004, divorce did not exist in Chile.[29] For simplicity we treat divorce, marriage annulment and de facto separation as equivalent in the model. The separation probability is specified as a logistic model,[30]

$$\pi^d\left(e^m, a_t^m, a_t^f\right) = 1 - \left(1 + exp^{-\pi_0 - \pi_1 a_t^f - \pi_2\left(a_t^f\right)^2 - \pi_3 e^m - \pi_4(a_t^m - a_t^f) - \pi_5\left(a_t^m - a_t^f\right)^2}\right)^{-1}.$$

Upon separation, a couple's non-pension assets A_t are split evenly between the two individuals who then become single households.

Recall that one feature of the pension reform was a change in the rules governing pensions upon divorce. Prior to the reform, divorce could lead to a loss of rights to a spouse's pension benefits. After the reform, in the event of a divorce or annulment, a judge can rule that up to 50 percent of one of the spouse's pension balance be transferred to the other spouse's account as a form of alimony. In our model, we assume that before the reform, divorced individuals only have access to their own pension funds. After the reform, each spouse gets one-half of the pooled wife's and

[28] We obtain these probabilities from life tables that are specific to Chile and are conditional on age and gender (RV-2004, from Circular 1314, published by the Superintendencia de Pensiones).

[29] Chile still has one of the lowest divorce rates in the world - around 3%. However, during the time period of our data it was even lower - around 1%.

[30] We tried fuller specifications, including for example both spouse's schooling levels, but pared down the set of regressors to those that were significant, to economize on parameters and minimize overfitting.

husband's pension savings. To reduce computational complexity and because divorce/separation in old age is relatively rare, we assume that no separation occurs after the woman turns age 60.

4.6 Fertility

The number of children N_t is assumed to evolve stochastically.[31] The probability of having another child is modeled as a logistic model, that depends on the woman's age, marital status, schooling level and number of children in the previous period.

$$\pi_t^N(N_{t-1}, a_t^f, e^f, m_t) = 1 - \left(1 + exp^{-\alpha_0+\alpha_1 m_t+\alpha_2 N_{t-1}+\alpha_3 N_{t-1}\cdot m_t+\alpha_4 e^f+\alpha_5 a_t^f}\right)^{-1}$$

There are assumed to be no births after the woman turns age 40.[32]

4.7 Evolution of other state variables

The model's other time-varying state variables, A_t, B_t^m, B_t^f, X_t^m, X_t^f are determined by the savings and labor supply decisions and by asset return shocks. Private savings are assumed to earn the risk-free rate r, assumed to be 5 percent.[33] The balances on each spouse's pension account accrue interest stochastically and are augmented by the current period's contribution. Returns on the pension accounts are modeled as an iid process: $r_B \sim iidN(\bar{r_B}, \sigma_B^2)$.[34]

4.8 Recursive formulation of the household's problem

The optimization problem a single individual of gender j faces has the following recursive formulation:

$$V_t^j(\Omega_t^j; \tilde{\epsilon}_t^j; k) = \max_{s_t, d_t^j, p_t^j} \left[u^j(S_t^j; k) + \beta \pi^{sj}(a_t^j) EV_{t+1}^j(\Omega_{t+1}^j; \tilde{\epsilon}_{t+1}^j; k)\right]$$

[31] Although it is conceivable that fertility might respond to changes in pension system design, a large response in our case is unlikely; because the increase in pension benefits occurs far in the future and is heavily discounted around child-bearing ages. Also, Todd and Wolpin (2006) found that fertility in Mexico did not respond to a fairly large increase (approx 20%) in income that families received as a result of the Progresa conditional cash transfer program.

[32] This assumption is made in part to reduce computational complexity.

[33] Chile's 10-year government bond yields oscillated between 4 and 6 percent over the period 2008-2018

[34] Individual returns will differ in part because people can choose different firms to administer their pension funds and choose different funds within those firms. These decisions are not incorporated into the model. Also, allowing for serial correlation in the pension fund returns would require adding past returns as additional continuous state variables, which would significantly complicate the model's numerical solution. However, see Krasnokutskaya, Li and Todd (2018) for an analysis of individuals' AFP fund administrator choices and of AFP fund pricing behavior.

s.t.

$$\begin{aligned} c_t^j &= (1-s_t)(y_t^j + A_t(1+r)) \\ A_{t+1} &= y_t^j + A_t(1+r) - c_t^j \\ A_{t+1} &\geq 0 \\ B_{t+1}^j &= B_t^j(1+r_B) + \tau \frac{w_{F,t}^j}{1+p_t^j} d_{1,t}^j \end{aligned}$$

where B_{t+1}^j denotes formal sector pension contributions. y_t^j is the household's income, and $\tilde{\epsilon}_t^j$ is a vector of shocks to wage offers, preferences for leisure, and pension asset returns. In addition to the constraints above that describe the evolution of pension and non-pension assets, the model includes the wage offer equations and the income/tax equation specified earlier.[35]

For couples, the continuation value embeds five possible events. Either both spouses die (the continuation value is 0 in this case), or the husband dies and the maximization problem continues with the wife, or the wife dies and the maximization problem continues with the husband, or both spouses survive and remain together, or both spouses survive and separate.

Incorporating greater detail about the different possible next period options, the recursive formulation of the couple's problem can be written as:

$$\begin{aligned} V_t^c(\Omega_t^c; \tilde{\epsilon}_t^c) = \max_{s_t, d_t^m, d_t^f, p_t^f} & \Big[\\ u^c(S_t^c; k) &+ \beta \cdot \Big(\pi^{sf}(1-\pi^{sm}) \cdot (1-\theta) EV_t^f(\Omega_{t+1}^f; \tilde{\epsilon}_{t+1}^f) \\ &+ \pi^{sm}(1-\pi^{sf}) \cdot \theta EV_t^m(\Omega_{t+1}^m; \tilde{\epsilon}_{t+1}^m) \\ &+ \pi^{sm}\pi^{sf}(1-\pi^d) \cdot EV_{t+1}^c(\Omega_t^c; \tilde{\epsilon}_{t+1}^c) \\ &+ \pi^{sm}\pi^{sf}\pi^d \cdot \Big[\theta EV_{t+1}^m(\Omega_{t+1}^m; \tilde{\epsilon}_{t+1}^m) + (1-\theta) EV_t^f(\Omega_{t+1}^f; \tilde{\epsilon}_{t+1}^f) \Big] \Big) \\ & \Big] \end{aligned}$$

[35] When we estimate the model, we constrain household consumption to be above a floor C_{min}. This avoids technical issues associated with infinitely negative utility levels and captures un-modeled government programs and private transfers that are available to families with extremely low earnings.

s.t.

$$\begin{aligned} c_t &= (1 - s_t) \cdot (y_t^c + A_t \cdot (1 + r)) \\ A_{t+1} &= y_t^c + A_t \cdot (1 + r) - c_t \\ A_{t+1} &\geq 0 \\ B_{t+1}^j &= B_t^j (1 + r_B) + \tau w_{F,t}^j d_{1,t}^j \quad j \in \{m, f\} \end{aligned}$$

The variables on which the separation and divorce probabilities depend were omitted above to ease notation.

The structure of the household problem remains the same after either member becomes eligible for pension benefits. Simply, household income is augmented by the contributory and non-contributory benefits described in section 3. Contributory pension withdrawals are deducted every year from the remaining pension balance and pension contributions are no longer deducted from formal labor income. Households continue to choose labor supply and consumption decisions to maximize the household's value function until age 75, and consumption decisions until death.

4.9 Identification

The key model features that jointly determine how individuals and couples respond to pension system design changes are (i) the model components determining labor supply decisions, including formal and informal sector wage offer equations, and non-pecuniary preferences for leisure and formality (ii) the returns on pension and non-pension savings and the parameters governing their relative substitutability, (iii) the processes governing fertility, divorce, and mortality, and (iv) whether the objective function and constraints pertain to a joint or single household. Although all these model features jointly govern how individuals respond to pension system reforms, we separately discuss the parameter identification for each of them. When parameters are estimated through generalized method of moments, identification depends on the particular moments chosen.[36] We therefore describe how the moments were selected to be able to identify different model parameters.

[36] In principle, the first-order conditions from the likelihood could be selected as the moment conditions in the GMM problem, but often this is not done due to computational complexity.

Wages are observed for individuals choosing to work in a particular sector, which is essentially a Roy model where workers choose the sector in which they have a comparative advantage. Identification of static Roy models is considered in Heckman and Honore (1990). The first paper to estimate a generalized Roy model in a dynamic discrete choice setting, including schooling, endogenous work experience, unobservable heterogeneity and nonpecuniary sector attributes, is Keane and Wolpin (1997). Given our assumptions on the error distributions, the wage offer equation parameters can be identified even without exclusion restrictions (as in Keane and Wolpin (1997)). However, our model does have exclusion restrictions, that is, variables that affect labor market participation decisions that do not affect wage offers directly, such as spousal characteristics, household assets and child status, which provide valuable sources of variation to identify the wage offer function parameters. Also, we model explicitly one of the important nonpecuniary components affecting sector choice decisions (formal/informal), namely, the fraction of wages that goes towards the mandatory pension contributions that will then not be available for immediate consumption. Moments relating to labor force participation and formal sector participation rates among subgroups defined by gender, age, marital status, number of children, schooling, experience and non-pension assets are included in the simulated method of moments criterion function to identify the impact of these variables on the disutility of work and non-pecuniary benefits in the formal sector. Conditional mean earnings by age, gender, schooling, experience, and cohort identify the effect of these characteristics on wages. The earnings shock variance is identified by moments relating to cross-sectional earnings dispersion. Labor supply transitions pin down switching costs in the utility function. Lastly, moments relating to the distribution of first-differences in earnings identify the permanent unobserved type distribution and their effects on earnings.

In our model, workers accumulate both pension and nonpension savings. Households face an implicit portfolio choice between a taxable liquid asset and a tax-deferred illiquid asset. The relative value of the two assets over the life-cycle reflects changes in the precautionary (self-insurance against income risk) and retirement motives for savings. The CRRA parameter α and the discount rate β determine the strength of the two savings motives at different ages. High values of β will unambiguously generate higher saving rates. On the contrary, in a finite horizon model with CRRA preferences, the effect of α on savings is theoretically ambiguous: α governs consumption-smoothing both over time and over realizations of income and asset return uncertainty. For example, a higher value of α implies higher saving rates if income uncertainty is high, but lower saving rates if the

current income level is low relative to a workers permanent income. Thus, different (α, β) combinations will imply different age profiles of savings. The observed age profiles of savings and income are the main sources of identification for these parameters. Our set of moments includes, for each age group, proportions of households in different asset level intervals to capture the dispersion as well as the mode of the asset distribution. In principle, this could allow us to identify heterogeneity in the CRRA parameter and the discount rate, but in practice this heterogeneity was not pinned down precisely so we did not allow these parameters to differ by unobserved type. Note that, when working formally, households in our model accumulate illiquid savings, which cannot be used to smooth consumption in the short-term, in addition to liquid savings. Therefore, labor sector choice by households with different levels of accumulated liquid and illiquid savings are also informative about their time and risk preferences.

Fertility and divorce are observed for subgroups distinguished by their observables. The parameters relevant to these processes are identified up to scale, because of the direct mapping between the parameters and the observed conditional probability distributions. The mortality process parameters are similarly identified. However, we do not observe enough deaths in our sample to be able to reliably estimate the mortality process and therefore use instead survival probabilities derived from population statistics.

In our model, the utility of a household is a weighted sum of the individual male and female utilities with fixed weights (set equal to 0.5). The individual utility parameters can be separately identified, because we also observe decision-making for households comprised of singles.

4.10 Model discussion

4.10.1 Incorporating the 2008 pension reform

We introduce the following key features of the 2008 pension reform into the model:
(i) *The New Solidarity Pillar.* The NSP is most beneficial to workers with low pension savings accumulations who otherwise would not have contributed long enough to qualify for the MPG under the old system. The NSP is expected to disproportionately benefit women.
(ii) *The per-child bonus.* The child bonus is provided only to women, regardless of whether they actually experience career interruptions upon giving birth.
(iii) *Change in divorce rules.* Wives can receive up to 50 percent of the husband's pension savings upon divorce.

Two reform aspects cannot be evaluated given our methodology. The first is the change in the premium paid by women per the Survivorship and Disability insurance, because the model does not incorporate health status, other than death. The second is the ability to make voluntary pension contributions while not working. Under the current system, it is already possible to voluntarily contribute to one's pension account above the mandated 10 percent level (a feature known as "Aporte Previsional voluntario") but this very rarely happens: fewer than 2 percent of the system's affiliates had positive balances in their voluntary contributions account in 2005 (own calculations). This is an indication that few individuals want to put more savings into the pension system than required by law. Given the additional complexity required and given the infrequency of voluntary contributions in the data, we did not incorporate this aspect into the model. The model does, however, include decisions about private savings but not the decision of whether to place the private savings into a tax-deferred pension account.

The model is dynamic and explicitly incorporates forward-looking behavior under a rational expectations assumption. It also incorporates uncertainty and incomplete information. Specifically, individuals are uncertain about future wage shocks, fertility, divorce or widowhood, survival and investment returns at the time of making labor supply and savings decisions. In solving the model, we assume that the 2008 pension reform came as a surprise and was not anticipated. Our discussions with the Budget Office in Chile indicated that the reform was not anticipated.[37] Thus, decisions up until 2008 are governed by a pre-reform decision model and decisions after 2009 are governed by a post-reform model. This requires solving two different versions of the model. First, we solve the dynamic programming problem (obtain the Emax values) assuming no reform and we estimate the structural model parameters only using pre-pension reform data. Then, fixing those parameters, we resolve the dynamic programming problem (i.e. obtain the Emax values that individuals use to form expectations) with the reform in place. These new Emax values are then used to simulate decision-making after the reform was introduced.

To a limited extent, the model incorporates business cycle effects in that returns on pension investments vary over time. Two limitations of the model are that investment returns are assumed to be i.i.d. and that there are otherwise no aggregate earnings shocks. However, the model is nonstationary and aggregate demographic time trends are incorporated in a few ways. First, the

[37] Modeling the reform as anticipated would have also been feasible but would require assumptions about when the details of the reform became known to workers.

initial conditions include the education levels of the husband and wife and rising levels of education with successive birth cohorts will lead to different decision-making over time. For example, more recent cohorts of women have higher education levels on average and the model will generate that they have fewer children and participate more in the labor force. Also, the model takes marital sorting patterns as initial conditions, so any temporal changes in marital sorting patterns can generate differences in behaviors across birth cohorts.

4.10.2 Incorporating labor market regulations

The model also incorporates important labor market regulations. For example, the progressive tax structure is taken into account in computing after-tax income. Fees that workers pay for health and disability insurance are also taken into account. Lastly, the model incorporates the fact that informal sector workers typically do not pay these taxes and fees.[38]

5 Description of the data

The estimation and simulations are based on data from three sources: the *Encuesta de Protección Social* (EPS) longitudinal survey, linked administrative records of pension balances and contributions to retirement accounts (obtained from the Chilean supervising agency for pension fund administrators (the *Superintendency of Pensions* or SP) and data on the returns achieved by Chile's pension fund administrators (the *Administradoras de Fondos de Pensiones*).

The EPS survey was first administered in 2002 (originally under the name *Historia Laboral y de Seguridad Social*) by the Microdata Center of the University of Chile. Originally, the sampling frame was individuals affiliated with the AFP or the older INP pension systems. The survey data were then linked to the administrative records of the pension accounts of the sampled individuals. In 2004, 2006 and 2009 three follow-up surveys were administered, and the sample was augmented to include individuals that were not affiliated to any pension program, for a total sample of 20,114 individuals.

The EPS questionnaire was designed specifically to study Chile's social protection programs including the pension system. It contains rich longitudinal information on socio-demographic variables, household composition, employment histories, earnings and assets. The data include retro-

[38] We use information on reported earnings and do not explicitly incorporate minimum wage regulation. However, we trim out reported monthly wages over 100 million pesos as they are likely to be reported with error.

spective employment histories back to 1981 as well as earnings from 2002 to 2006 and household assets in 2004-2006.We merge the household survey data with the administrative data on pension savings accumulations.

The main variables used in estimation are age, schooling level, schooling level of the spouse, an indicator for the birth of a child in the current year, ages of all children, number of years the respondent worked in the formal sector, number of years the respondent worked in the informal sector, labor sector choice, labor sector choice of the spouse, annual earnings and private household wealth.[39] For employees, we proxy formality using a specific question in the EPS survey that asked about having a written work contract. Self-employed workers are considered part of the informal (or non-contributing) sector.[40]

Our population of interest is the Chilean population before the reform, conditional on the age restrictions specified below. Therefore, our starting point in building our estimation sample are the 16,150 respondents who were interviewed in the 2006 round (the last round before the reform), and are representative of the Chilean population in 2006. 2004 corresponds to the initial conditions in our model and the starting point of our simulations. To arrive at our estimation sample, we impose the following sample restrictions:

(i) Our model incorporate the rules of the AFP pension system. We excluded from the estimation sample workers who reported only making contributions to a pension system other than AFP. However, we incorporate workers who worked before 1980 and accumulated some pension rights under the previous pension system and then switched to the AFP system. In the model, the value of these rights is captured through the value of their Recognition Bond ("bono de reconocimiento"), which we add to the funds accumulated in the AFP account upon retirement.[41]

(ii) Incorporating marriage decisions is not feasible given the model's complexity. We use in estimation individuals who are 35 or older in 2004 (the year in which we start simulating our sample's decisions), an age when most people's marital status has already been determined. We excluded respondents who reported getting married after the age of 35.

(iii) We excluded households with missing information on key variables and with inconsistencies

[39] We construct a wealth measure that also includes the reported value of equity in major household assets, such as the home and car.

[40] A small fraction of self-employed individuals did contribute to the AFP system but the key point is that they were not required to do so in the years we consider, so their contributions can in that sense be considered voluntary.

[41] We obtained a dataset on the recognition bond values from the Superintendence of Pensions, which we linked to the survey data.

across survey rounds with respect to age, education and civil status (2,502 respondents).
The final sample contains 6109 households, some consisting of a single person and some of a couple, for a total of 5482 women and 4843 men.

Tables 1 and 2 present summary statistics for the estimation sample and for all EPS respondents, imposing only the age restriction. Table 1 shows demographic and labor force participation information whereas Table 2 describes the distribution of earnings, non-pension assets and pension assets, in millions of Chilean pesos.[42] A potential concern is whether our sample restrictions might disproportionately exclude poorer households, who are the target of the pension policies we are evaluating. As Table 2 shows, the distributions are very similar, except in the right tail of the earnings distribution. The estimation sample contains a slightly smaller proportion of high earning individuals households, which is unlikely to affect our conclusions.

The rest of the sample characteristics are also very similar before and after imposing the sample restrictions. Two thirds of the sample are couples and most of the single households are women. Women are a lot less likely than men to be working (31.9 percent versus 73.5 percent). Among workers, women are slightly less likely to be working in the formal sector than men. The high average age (51.5 for men and 50.9 for women) is due to the fact that the estimation only incorporates workers over age 35 years at the time of the first survey (2004).

6 Estimation results

Model parameters are estimated by the Method of Simulated Moments (MSM). This method was chosen, in part, because it more easily accommodates missing state variables than does simulated maximum likelihood, which would require numerical integration over all possible missing state variable values. Our estimation approach uses information from the 2004 EPS survey to construct the initial conditions and state variables (as described in section 4), simulates 4 periods ahead to get 2005-2008 outcomes, and minimizes the distance between the actual and the simulated outcomes. Details of the estimation procedure and standard error computation are provided in section A.2.

This section first discusses the estimated values for key parameters of interest and the model's within-sample fit. Then, we describe the out-of-sample pension reform predictions and how they compare to reform impacts estimated in other reduced-form studies.

[42] The responses for each type of asset holding (housing, cars, etc.) have been top coded at 1 percent to reduce the effect of outliers/miscoding.

6.1 Parameter estimates

Tables 3 and 4 provide the parameter estimates and associated standard errors related to preferences (for work and savings) and labor market opportunities, which for the most part align with estimates reported in the literature. The degree of risk aversion η is estimated to be 2.7. The structural labor literature typically estimates values between 1 and 5 (van der Klaauw and Wolpin, 2008) and the discount factor is estimated at 0.999 (French and Jones, 2011, report estimates between 0.85 and 1.12). We find that not working contributes negatively to the marginal utility of consumption of both genders, which is consistent with a substitution between consumption expenditures and home production. The coefficient is more negative for men than for women (-5.0 vs. -3.1) , which generates the lower labor force participation rates observed among women. The estimated utility of leisure (Ul) parameters indicate that married women, women with children and women who work part-time derive greater utility of leisure.

The parameter estimates provide some insights into what leads individuals to work formally or informally, which is helpful in understanding heterogeneous behavioral responses to pension policies. First, we find significant costs to switching between the formal and informal sectors for both men and women. The costs are similar in magnitude to the cost of re-entering the labor market after a period of not working. The switching costs are higher for men and the entry costs higher for women. These costs represent labor market frictions that will tend to mitigate labor supply responses to pension policy changes.

Second, we find heterogeneity in the way individuals value informal sector work, as captured by the estimated unobserved type coefficients. Some types incur non-pecuniary costs when working informally (types 1, 2 and 3 for women and type 2 for men), while other types perceive benefits. This heterogeneity may reflect differences in individuals' attributes that affect suitability for informal sector work as well as preference heterogeneity. Table B7 tabulates household characteristics by unobserved heterogeneity type.

Turning to the estimated parameters of the formal and informal log earnings offer equations (Table 4), we find that the estimated intercept varies significantly across types. For example, for a given schooling and experience level, type 4 males have higher earnings offers in the formal sector, but their informal earnings offers are similar to other types. Thus, type 4 males have a formal sector comparative advantage.

Additionally, the estimated returns to schooling and experience, both allowed to be quadratic, differ in the formal and informal sectors. For example, for men, the informal sector offers lower returns to experience. The returns to schooling are initially higher in the informal sector and then lower as schooling levels increase in comparison to the formal sector. Heterogeneity in schooling levels is an additional source of comparative advantage to working in the formal sector.[43] Moreover, once a worker accumulates sufficient levels of formal sector experience, he would be unlikely to switch to the informal sector where the returns are much lower. Taken together, these sources of heterogeneity in demographics and in how individuals value pecuniary and non-pecuniary dimensions of formal and informal work will influence whether they adjust their labor supply in response to pension system changes. If many individuals have a strong comparative advantage in the formal sector, their behavioral response to pension system changes will be muted.

Lastly, we estimate a significant non-pecuniary cost to working past the legal retirement age (LRA) for men (Table 3). The discontinuous drop in labor force participation at the legal retirement age observed in the data could, in principle, be explained in two ways within our model. The first is that borrowing constrained individuals have to wait until their pension benefits become available. However, conditions for early pension claiming in the Chilean system are relatively easy to satisfy (see section 3) and do not carry a discontinuous penalty in pension benefits as is typical under defined benefit schemes. This suggests that there may be non-financial motives to retiring exactly at the legal retirement age. The estimated cost of working past the legal retirement age (LRA) for women is smaller and statistically insignificant; the labor force participation drop off at the LRA is less pronounced for women than for men.

6.2 Model fit

To evaluate the ability of the model to capture the key patterns in the data, we use the estimated model to simulate each sampled household's labor supply and savings behavior in years 2004-2008 from the observed 2004 initial conditions. Figure 2 shows the labor force participation rates for men and women as they approach the standard retirement age. The model captures the low female labor force participation rate in Chile in comparison to males, and the decline of employment for both men and women near retirement. It slightly overpredicts the labor force participation rate for

[43] Younger birth cohorts have higher schooling levels on average and therefore tend to have stronger attachment to the formal sector.

men at some ages.

Figure 3 shows the fraction of workers in the formal sector with different levels of formal sector experience. The model captures the "lock-in effect" observed in the data, namely that individuals become less likely to switch sectors the longer they work in one sector. The higher the formal sector work experience level, the higher the proportion working in that sector for both males and females.

Figure 4 shows the distribution of earnings in both sectors as observed in the data and as simulated by the model. The model captures that formal sector wages are substantially higher and have greater variance. It also captures the skewness in both the formal and informal sector distributions. The model does not capture the small group of informal sector workers with very high earnings (who tend to be self-employed). This group is unlikely to be much affected by reforms to the pension safety net and therefore are not the primary focus of this study.

Figure 5 shows the distribution of non-pension assets in the model and in the data. The model fits the basic features of the wealth distribution, although the proportion with wealth holdings in the lowest category is somewhat higher under the model than in the data.

6.3 Predicted short-run reform impacts and comparison with existing studies

We next evaluate the short-term impact of the 2008 pension reform and compare our model's predictions to reform impacts that have been estimated in a few reduced form studies. To this end, we simulate decision-making and outcomes in each year up until 2015 under two scenarios. In the first scenario, we incorporate the reform as it was implemented. In the second, we simulate behavior under the old system as if there had been no reform. The difference in pension levels, labor force participation patterns (including the formal/informal sector break-down) between those two sets of simulations can be attributed to the pension system changes, keeping other factors (including any general demographic time trends) constant.

Figure 6 shows the distribution of simulated pension levels under the old system (without the 2008 reform) and with the reform for both men and women and by marital status. The four graphs on the right refer to women and show that the fraction with no pension is dramatically reduced as a result of the reform. Moreover, a significant number of unmarried men and women who qualified only for PASIS under the old system now receive the higher PBS pension. Less intuitively, two-person middle-class households appear to be the main beneficiaries of the reform. Married women who did not contribute to the system often did not qualify for any benefits prior to the reform,

because their household income was too high to be eligible for the PASIS pension. Many of these women receive the PBS pension after the reform, due to the much larger coverage of the PBS (the first six deciles of the household income distribution).

Figure 7 (left panel) plots a Lorenz curve to analyze inequality in individual pension receipt (combining men and women). It shows that the reform strongly impacts inequality at all deciles above 10%. However, if we consider a household-level inequality measure (figure 7, right panel), the impacts are significantly smaller. The right panel figure shows that households just above the median level household (in terms of combined pension benefits) benefit more from the reform than the poorest households.

Table 5 shows the simulated effect of the reform on labor force participation at different ages. There is evidence of substantial heterogeneity with respect to age, schooling levels and marital status. At younger ages (age 50-59), men increase their labor force participation in response to the reform, but at older ages (ages 60-74) they decrease it. For women, we observe a pronounced decrease in labor supply at older ages starting around age 60, which is before the basic pension claiming age of 65. This is because the model allows individuals to modify their labor supply in anticipation of future income, either financing consumption from their spouse's income or non-pension savings for a few years.

There is also heterogeneity in labor force participation responses with respect to schooling levels. Men without high school increase labor supply, but as the level of education increases the effect on labor force participation becomes negative. For women, the negative impact of labor force participation is greatest for those with less education (who also tend to be older). Disaggregating by marital status, we see that the reform increased the labor supply of single men but decreased it for married men.

The positive labor force participation impacts are concentrated among men who were most likely to qualify for the old system safety net. The old system had a stringent means-test determining eligibility for the basic pension, which essentially imposed a higher implicit marginal tax rate on earnings over a range in comparison to the new pension system rules. The new system is also more generous, which explains why the wealth effect dominates at older ages, allowing individuals to stop working earlier than they would have under the old system.

The differential response by marital status is not surprising when considered in relation to household-level pension benefits. Recall that the largest jump in pension benefits occurs for married

women in households who are not poor enough to receive PASIS but who are eligible for the PBS (i.e. they are under the 60% PBS means-test threshold). Our simulations show that their husbands respond to the additional pension income by retiring earlier. Women's labor supply decreases but to a lesser extent. Formal sector participation (unconditional on working) shows similar patterns as overall labor force participation (the previous table), but with slightly larger magnitudes (Table 6). The fact that the formal sector work decrease is larger than the labor force participation decrease shows that there is some switching from formal to informal work.

Despite a large descriptive literature on the 2008 reform, thus far only a few studies have attempted to isolate the behavioral responses to the 2008 Chilean pension reform using either quasi-experimental or structural estimation methods.[44] Behrman, Calderon, Mitchell, Vasquez, and Bravo (2011) analyze the effects of the PBS (the Basic Solidary Pension) on household income as well as on outcomes related to household work, health status, expenditures on alcohol and cigarettes, health insurance and ownership of consumer durables. They use a difference-in-difference approach to compare the change in income/outcomes over time for treated families that qualify for the PBS (by virtue of being poor and having a family member over age 65) and households that are either non-poor or do not have a family member over age 65 and therefore do not qualify for PBS. The pre-treatment year is 2006, two years before the reform, and the post-treatment year is 2009, one year after the reform.[45] Behrman et al. (2011) find that PBS eligible households had 2.4 percent more household annual income relative to non-targeted households. In addition, targeted households report more leisure hours, which is consistent with the lower labor force participation we predict at older ages.

Using the same data, Encina (2013) applies a difference-in-difference with matching methodology to PASIS recipients, and finds that receiving the more generous PBS benefit causes them to reduce their labor force participation by 18 percentage points relative to eligible households who do not report receiving PBS. This negative wealth effect in a sample of individuals above 65 is qualitatively consistent with our simulations. The larger magnitude is not surprising since the

[44] Packard (2002) was the first to study the frequency of contributions over the life-cycle and their determinants in Chile, using limited dependent variable models of self-reported contribution densities elicited in PRIESO, a cross-sectional household survey.

[45] An implicit assumption of Behrman et. al.'s (2011) difference-in-difference approach is that households who do not qualify for the program at a point in time do not anticipate that they may qualify at some future time period, which could affect their current behavior even if they are not actively receiving benefits. The dynamic structural modeling framework used in this study explicitly incorporates such possible anticipatory effects.

estimate corresponds to the subsample of the elderly whose benefits increase the most.

Another study by Attanasio, Meghir and Otero (2011) examines the effects of Chile's pension reform on formal and informal labor market participation. Following an approach previously used by Attanasio and Rohwedder (2003) and Attanasio and Brugiavini (2003), the study exploits variation in the intensity with which different groups were affected by the reform to estimate the relationship between expected pension wealth, expected accrual rates and a variety of outcomes. Using forecast equations to predict future wages and labor supply, they build expected pension wealth and accrual rates with and without the reform. Attanasio et. al. (2011) find that the increase in pension wealth upon retirement implemented by the reform reduced the rate of participation in formal sector jobs, by around 4.1 percent for older workers, which aligns with our results on older workers. Two ways our results differ are that their estimated behavioral changes are larger for women than for men and they do not find increases in labor supply at younger ages. The first difference can be explained by the fact that they do not model, as we do, the income effects that impact married men through increased government transfers to their spouses. As for the second difference, they do not model the relaxation of the basic pension's means-test to which we attribute the predicted increased labor supply at younger ages.

As Attanasio et. al. (2011) note, relying on reduced-form forecast equations can miss part of the reform impacts: "One important difficulty in calculating pension wealth is that future labor supply will change as well as current one, as a result of the reform. In order to capture the relationship completely, a fully specified dynamic model should be used." Our structural framework allows us to go beyond short-term impact evaluation to make predictions about long-term pension reform impacts and study the effects of hypothetical pension program designs that differ significantly from the one implemented. These topics are considered in the next section.

7 Analysis of the reform design

A major benefit to estimating a structural model is that we can use the model to evaluate the effects of alternative pension system designs. We focus on design changes that have been proposed by policy makers as possible ways to achieve further reductions in the gender pension gap. The impact on gender pension gaps that we simulate incorporates both any mechanical impact due to changes in the pension benefits for which women and men are eligible and any behavioral responses

induced these new rules, both of which can affect gender pension gaps. We report the impacts not only on pension benefits but also on labor supply, formal sector work, government costs, and private savings.

For each actual and hypothetical pension system design, we assume that the reform (if any) took place in the year 2008 and we report outcomes for years 2009-2028, which is when the youngest cohort in our sample reaches the female retirement age.[46] As previously discussed, we assume that the reform was not anticipated. These simulations assume that the youngest cohorts are exposed to the new pension rules at most half of their career. The simulations do not capture the effect of being subject to the new pension system over one's entire working life. However, governments are often interested in how populations are affected over medium-term horizons.

7.1 Sources of gender pension gaps and reform designs

Our baseline scenario for purposes of comparison is the 2008 pension reform as implemented (described in the section 3). We analyze which features of the pension reform are most important to achieving the gender pension gap reductions by perturbing the current pension system design in various ways. We also consider the cost to the government of the alternative pension system designs, incorporating changes in tax receipts induced by labor supply and workforce composition changes.

We examine the following scenarios, where the last seven represent modifications to the existing (2008) pension system.

0. The old pension system is kept in place (i.e. no reform)

0bis. The old pension system is made gender neutral

1. The actual 2008 pension reform as implemented (baseline)

2. The legal retirement age of women is raised to 65 (equal to men's)

3. When a married woman does not contribute, half of her husband's contribution goes to her account (5% to each)

[46] In order to match observed post-reform trends in separation rates, we exogenously impose an increase in the probability of separating of 1pp for all scenarios after 2009. We also ran simulations in which separation rates only increase in the reform scenarios, which is equivalent to attributing the increase in separation rates to the reform itself, but our results are essentially unaffected.

4. When a married woman does not contribute to her pension account, her husband has to make a full contribution to her account in addition to his own (10% each)

5. Gender neutral tables are used to compute pension benefits

6. The reform is implemented without the child bonus

7. The reform is implemented without the divorce rule

8. The reform is implemented with a 100% claw-back rate

9. The reform combines all features above (equal retirement age, split contributions, gender neutral tables, child bonus, divorce rule)

Scenario 0bis is designed to isolate the portion of the gender pension gap that comes from differences in the rules affecting men and women in the old system. The scenario equates the legal retirement age of women with that of men and uses the same life tables to compute pension withdrawals for men and women.[47] The gaps in pension income isolated in this way will be compensated, in terms of pension wealth, by the fact that women receive benefits over a longer number of years on average. The gender pension gap remaining in that scenario therefore corresponds to differences in preferences (leisure, formal sector etc.), but also in earning opportunities and initial characteristics.

In Chile, the retirement age is lower for women than for men (60 vs. 65). When women reach their retirement age (60), they have a lower accumulated balance and must finance a longer retirement period than if they claimed a pension starting at age 65. This results in lower monthly benefits. Scenario 2 simulates the effect of equating the retirement age for men and women. A comparison of the gender pension gap under scenarios 1 and 2 shows how much of the gap is attributable to the gender difference in retirement ages. Under the current system, women have the option to delay claiming their pension benefits until age 65. Thus, raising the retirement age of women places a constraint on behavior and, in the context of our model, imposing any constraint would lower welfare for women (and for their husbands) despite increasing their pension benefit levels.

[47] Specifically, we use the life tables corresponding to women to compute men's withdrawals

Scenarios 3, 4, 6 and 7 consider different ways of addressing the fact that women, particularly married women, tend to have lower contribution densities than men. That is, they reach retirement having contributed fewer months, because they are much more likely to have spent time caring for children or dependent adults. In Chile, the labor force participation rate of women was particularly low by international standards among the cohorts considered for this study.[48]

As a way to fill the gaps in contribution histories, scenarios 3 and 4 require married men to contribute on behalf of their wives if they are working and their wives are not.[49] In scenario 3, the 10% contribution is allocated equally (split) to the husband and wife's account. In scenario 4, two 10% contributions are subtracted from the husband's formal income and put in each of their accounts.

The 2008 reform adopted a different approach to the problem of career interruptions related to childbearing. The child bonus subsidizes women's pension accounts in proportion to the number of children they had. To isolate the effect of this feature of the reform, we simulate the reform without the child benefit in scenario 6 and contrast it to the baseline. Lastly, scenario 7 simulates the 2008 reform without the provision that pension savings can be split between spouses in the event of a divorce, particularly if the wife is facing a drop in her living standards.

In a pension system based on individual capitalization accounts, women's greater longevity reduces their monthly pension benefits relative to men. The capital accumulated on the account at retirement must cover a greater number of years in expectation. An alternative that would potentially favor women at the expense of men is to use gender-neutral life tables for the purpose of computing monthly pension benefits. That is, the probabilities of survival for an individual of either sex at each age are estimated from all individuals of that age rather than being computed separately for men and women. As a result, survival probabilities are overestimated for men and underestimated for women. In scenario 5, we simulate a simplified version of this change in which women's pension benefits are computed using the male life tables.

Scenario 8 considers the effect of using a 100% claw-back rate to compute the minimum pension. This amounts to topping up pension benefits up to the PBS amount if they are lower than that level. It is not a priori obvious whether this feature of the reform benefits men or women.

In scenario 9, we combine all considered reform features that benefit women: equal retirement

[48] In the early 2000s, female labor force participation was still only in the upper 30s. It has since reached 50% with the addition of younger cohorts into the labor force.

[49] To simplify the interpretation, we do not require working women to contribute for their non-working husbands.

age, an extra 10% contribution (as in scenario 4), gender neutral tables, child bonus, and the divorce rule.

7.2 Impacts of reform designs on the gender pension gap

Table 7 shows the male female gender pension gap for new retirees in different income, education and work experience subgroups. Comparing the actual and gender-neutral versions of the pre-2008 system (scenarios 0 and 0bis), we find that the gender pension gap drops from 44.3% to 27.2%, or a 38.6% decrease. This is the portion of the gap before the reform that is due to features of the pension system that treat men and women differently, namely the lower retirement age for women, and the different life tables used to compute the amount that can be withdrawn annually. The remaining gap of 27.2% (61.4% of the total gap under the pre-2008 system) can therefore be attributed to differences in men and women's initial conditions, preferences and labor market opportunities.

Comparing columns 0 and 1, it is clear that the pension reform significantly reduced the gender pension gap from 44% to 23%. The main impact is found in terciles 1 and 2 of the pension benefits distribution; women with low contribution densities benefit the most from the more generous safety net. In fact the average pension benefit in the bottom third of the distribution for women was almost 0 under the old system because many women (particularly married women), never worked formally nor qualified for a safety net benefit. Examining gender pension gaps by schooling reveals that women with the lowest education levels had the highest gender pension gaps prior to the 2008 reform, which reduced the gap by nearly 30 percentage points.

One of the notable features of the 2008 pension reform was the reduction in the number of years of formal work experience required to qualify for a minimum pension. For this reason, workers with lower levels of formal work experience (both men and women) became eligible for greater pension benefits. Women are more likely to have low levels of formal sector work experience, because of lower rates of labor force participation and careers interrupted by childbearing. Table 7 shows that the largest reduction in the gender pension gap, from 17% to 0% occurred for women with less than 10 years of formal work experience. Given the low labor force participation rate of married women, the gap for married individuals exhibits a bigger reduction than for singles. For women with strong formal work attachment (more than 20 years work experience), the initial pension gap was much lower and the pension reform all but eliminates it.

In addition to more generous transfers for workers with sparse contribution histories, the 2008 pension reform included provisions to compensate women for time spent in childbearing and we would naturally expect this aspect of the reform to have the greatest impact on women with more children. Women with 3 or more children saw a large reduction in the gender pension gap (from 60% to 32%), whereas women with no children saw a small increase in the gap. However, as seen in column 6, the bulk of the reduction in the gender gap would have been accomplished with the reform even without the child bonus feature.

We also isolate the impact of the progressive claw-back feature which is described in section 3. Removing this feature implies that the minimum pension is now a simple top up to the value of the basic pension PBS. The resulting gender pension gap is almost identical to that of the baseline reform, indicating that the rate of claw-back does not impact men and women differently.

Turning to pension design elements that were not included in the reform, column 2 shows that the gender pension gap could be reduced further by delaying women's standard retirement age to be the same as that for men (from 23% to 12%). Of note, these gains are concentrated in very different subgroups than those affected by the actual reform. The gap diminishes the most at higher terciles (of pension benefits), schooling and formal experience levels.

The other design changes shown in the table also reduce the average gender gap but have more modest impacts. Taken together, scenarios 6,7 and 8 indicate that the more generous basic pension (PBS) can be credited with the bulk of the reduction in the gender pension gap.[50] The pension system design that combines all the features (column (9)) leads to a pension surplus for more educated women and for women with a lot of formal sector experience and reduces the overall general benefit gap to 4%.

7.3 Impacts of reform designs on labor supply, savings and program costs

In section 6.3, we identified some negative short-term behavioral impacts of the reform on labor force participation. However, such effects may differ in the longer run as cohorts who are affected by the reform at earlier ages and have more time adjust their behavior retire. A second question is whether the effect of behavioral responses over a person's career compounds to a large effect on pension saving accumulation. Table 8 examines how the 2008 pension reform and the various

[50] We confirm this by simulating a reform that only modifies the basic pension (PBS) and find that it accounts for two-third of the reduction in the pension gap achieved by the reform

perturbations of its design (described above) affect labor supply and savings behavior over the 20 years following the reform. Each table entry shows the outcome measure as a percentage of the outcome observed in column 1.

For example, as shown in columns 0 and 1, the pension reform's short-term negative effect on male or female labor supply at ages 60-65 translate into very modest effects on total years contributed (-0.2% and -0.3% for men and women respectively). This is because the labor supply decrease is limited to this age group, happens mostly in the informal sector and tends to dissipate in the longer run. Therefore, behavioral responses do not offset the gender pension gap reductions achieved by the more generous pension benefit rules.

In contrast, raising the female retirement age from 60 to 65 (column 2) increases female labor force participation by 14.2% between those ages as liquidity-constrained households substitute pension income with labor income. For the reasons stated in the previous paragraph, the reform only modestly (0.6% and 1%) increases the stock of years contributed. As shown in the row labeled "pension assets," women's pension assets increase substantially by 38.1% if the standard age of retirement for women increases. Given that years contributed are not impacted, this effect can be attributed to the delayed withdrawal and the fact that pension assets accrue interest for up to five additional years.

Other pension features have little impact on labor supply and years contributed. In particular, though mandating that husbands contribute to their nonworking spouse's pension (columns 3 and 4) is an implicit tax on wages, it does not appear to substantially affect labor supply. In the absence of large behavioral responses, spousal contributions impact the accumulated pension assets of men (upwards) and women (downwards) in the expected way.

Column 6 reveals the quantitative importance of the per child bonus: removing it reduces pension assets by 17% on average. This change in pension wealth has a negligible effect on labor force participation around retirement and total years contributed. Imposing gender neutral life tables also substantially reduces pension assets at age 65. However, this is because the programmed withdrawals made by women between age 60 and 65 are larger than in the baseline scenario, resulting in more depleted pension accounts by age 65.

The row labeled "household assets" shows that the pension reform did not decrease household assets, indicating that the pension system does not crowd out private savings. This is not surprising because the population segments that were targeted by the reform accumulate very little private

savings. The reform does however increase household consumption by 8.5% on average. This effect is in part due to the lower claw-back rate, as shown by column 8. Changing the rule about division of assets upon divorce appears to reduce incentives to save outside the pension system. Theoretically, splitting pension assets should reduce the marginal benefit of saving outside the pension system for women (who will benefit from the asset transfer) and increase it for men. Therefore, the impact of incentives for a married couple faced with divorce risk are a priori ambiguous. Our simulations predict that household assets are higher under the prior divorce rule, i.e. when pensions were not divided between spouses.

The last row compares the different pension system designs in terms of government costs. Increasing eligibility for the minimum pension entailed significant costs. A comparison of columns 1 and 0 shows that the cost of the old pension system was 52.6% of the cost of the post-reform pension design. The child bonus also significantly increased costs; excluding this feature would have resulted in 8.2% lower costs. The reduced claw-back rate introduced by the reform has a large impact on costs: moving to a full-claw back reduces costs by 14.1%. This feature is sometimes expected to improve incentives to contribute but this does not materialize in our simulations.

8 Conclusion

This paper develops and estimates a dynamic discrete choice model of household labor supply, pension and non-pension savings, and retirement. The model incorporates individual's and couple's decisions about whether to work in the formal sector, where they pay taxes and make mandatory pension contributions, in the informal sector or not at all. The consideration of how government policies affect incentives to work in the formal or informal sector is important to many economies around the world, including so-called developed countries.

The model that we develop and estimate is detailed enough to capture important institutional features of the 2008 Chilean pension reform, such as how the pension benefit levels depend on numbers of children, changes in the rules for dividing pensions upon divorce and changes in the payout formulae for pensions (based on actuarial life tables for men and women). A unique aspect of our model relative to other models estimated in the retirement, pension, and savings literature is that we continue to follow individuals after they become widowed or separate. This is important, because separation and widowhood are among the major economic risks facing older age women.

Two primary goals of Chile's 2008 pension reform were to reduce old age poverty and to reduce the gender pension gap. We use our estimated model to explore the heterogeneous impacts of the 2008 pension reform and to study implications for gender pension gaps and household inequality. We also use the model to analyze the impact of changing the current pension system design along various dimensions. Lastly, the model is used to simulate the government cost of alternative pension system designs.

Model parameter estimates show that the returns to education and the returns to experience are higher in the formal labor market sector. Once individuals gain substantial formal sector experience, they are unlikely to switch sectors. The parameter estimates also reveal significant labor market frictions in the form of sector switching costs, which have implications for how individuals respond to pension system changes.

Results based on simulating the estimated model show that the 2008 pension reform substantially decreased the pension gender gap, especially for women with lower levels of education, lower levels of formal sector work experience and for women with children. However, for some of these groups a sizable gap remains even after the reform (e.g. the 27%-39% gap for women with less than a high school degree). Two of the most important features of the current pension system design that reduced the gender pension gap are the expansion in eligibility for the basic solidarity pension (PBS) and the per child bonus.

The model simulations show that household structure is an important determinant of pension policy reform responses. Even though many of the reform features were targeted at women, we find that men's responses are sometimes greater than those of women as men respond to the wealth effect of their wives' increased pension benefits. This wealth effect leads both older men and women to retire earlier. We also find, however, that younger men (age 50-59) increase their labor supply. Our model simulations suggested that this increase is concentrated among relatively low income men. For these men, the pension reform relaxed the means test to qualify for a minimum pension, lowering an implicit marginal tax rate on their wages. We observe little impact on women's labor force participation at younger ages. In addition, the reform generates some switching from formal to informal sector work, particularly for older and more educated individuals.

The main beneficiaries of the reform are married couples with joint pension benefits just above the median level. These tend to be households in which the husband earned a sizeable pension—excluding them from for the PASIS minimum pension prior to the reform—but the wife did not

contribute to the pension system and thus qualifies for the PBS benefit after the reform. Inferences about changes in pension inequality differ substantially when the analysis is done at the individual or the household level (as seen in Figure 7). The 2008 pension reform had heterogeneous effects on labor force participation with respect to education and number of children. The gender pension gap reduces substantially for less educated women with three or more children.

Theoretically, increasing government transfers later in life could discourage private savings. However, the population segments that were targeted by the reform accumulate very little private savings and we do not find any evidence that the pension reform crowded out private savings.

Overall, our analysis shows that the 2008 pension reform largely achieved the government's stated goals of reducing old-age poverty, inequality and gender pension gaps. However, these benefits came at some cost, as the post-2008 pension reform is on average double the cost of the old system. The counterfactual simulations showed that increasing the mandatory retirement age of women to be the same as that of men (age 65 instead of age 60) would be a design change that would further reduce the gender pension gap and also substantially reduce monetary costs.

References

[1] Acuña, Rodrigo and Augusto Iglesias (2001) "Chile's pension reform after 20 years." Washington D.C.: The World Bank, Discussion Paper 0129, December.

[2] Joseph G. Altonji and Lewis M. Segal (1996) "Small-Sample Bias in GMM Estimation of Covariance Structures" Journal of Business & Economic Statistics , Vol. 14, No. 3 (Jul., 1996), pp. 353-366

[3] Arenas de Mesa, Alberto, Jere Behrman, David Bravo, Olivia Mitchell and Petra Todd (2007), "The Chilean Pension Reform Turns 25: Lessons from the Social Protection Survey," ed. Stephen Kay and Tapen Sinha, in Lessons from Pension Reform in the Americas, Oxford University Press, 2007. Pages 23-58.

[4] Arenas de Mesa, Alberto and Veronica Montecinos (1999), The privatization of social security and women's welfare: gender effects of the Chilean reform. *Latin American Research Review.*

[5] Attanasio, Orazio and A. Brugiavini (2003): "Social Security and Household Saving," *Quarterly Journal of Economics*, Vol. 118, No. 3, pp. 1075-1119.

[6] Attanasio, Orazio and S. Rohwedder (2003): "Pension wealth and household saving: Evidence from pension reforms in the United Kingdom," *The American Economic Review*, Vol. 93, No. 5, pp. 1499-1521.

[7] Attanasio, Orazio, Meghir, Costas, and Andres Otero (2011): "Pensions, Work and Informality: The impact of the 2008 Chilean Pension Reform," manuscript, University College, London.

[8] Auerbach, Alan J., and Laurence J. Kotlikoff (1987). Dynamic fiscal policy. Cambridge University Press.

[9] Blundell, Richard, Eric French, and Gemma Tetlow. (2016): "Retirement incentives and labor supply." Handbook of the economics of population aging. Vol. 1. North-Holland. 457-566.

[10] Behrman, Jere R., Maria Cecilia Calderon, Olivia S. Mitchell, Javiera Vasquez, and David Bravo (2011): "First-Round Impacts of the 2008 Chilean Pension System Reform," PRC WP2011-03. http://www.pensionresearchcouncil.org.

[11] Berkovec, James and Steven Stern (1991): "Job Exit Behavior of Older Men," in *Econometrica*, Vol. 59, No. 1, 189-210.

[12] Bertranou, Fabio (2001) "Pension reform and gender gaps in Latin America: what are the policy options?" World Development, 29(5).

[13] Blau, D.M., Gilleskie, D.B. (2006): "Health insurance and retirement of married couples" Journal of Applied Econometrics 21, 935-953

[14] Blau, D.M., Gilleskie, D.B., 2008. "The role of retiree health insurance in the employment behavior of older men." IER 49(2), 475-514.

[15] Borella, Margherita, De Nardi, Mariacristina and Fang Yang (2019): "Are Marriage-related Taxes and Social Security Benefits Holding Back Female Labor Supply," *NBER working paper* #26097.

[16] Casanova, Maria (2010): "Happy Together: A Structural Model of Couples' Joint Retirement Choices," working paper, UCLA.

[17] Cohen, Alma, Rajeev Dehejia, and Dmitri Romanov (2013): "Financial incentives and fertility." in *Review of Economics and Statistics* vol. 95, issue 1, 1-20.

[18] Conesa, Juan C., and Dirk Krueger (1999). "Social security reform with heterogeneous agents." Review of Economic dynamics 2.4: 757-795.

[19] Dammon, Robert M., Chester S. Spatt, and Harold H. Zhang (2004): "Optimal Asset Location and Allocation with Taxable and Tax-Deferred Investing," in The Journal of Finance, Vol. 59, No. 3, 999-1037.

[20] Dion, Michelle. "Pension reform and gender inequality." Lessons from pension reform in the Americas (2008): 134-163.

[21] Encina, Jenny. "Pension reform in Chile: A difference in difference matching estimation." Estudios de economa 40.1 (2013): 81-95.

[22] Fajnzylber, Eduardo. "Gender Policy and Pensions in Chile." Nonfinancial Defined Contribution Pension Schemes in a Changing Pension World: Volume 2 Gender, Politics, and Financial Stability 2 (2012): 113.

[23] Fields, Gary S. and Olivia S. Mitchell (1984): "The effects of social security reforms on retirement ages and retirement incomes," in *Journal of Public Economics*, Volume 25, Issues 1-2, p. 143-159.

[24] French, Eric (2005): "The effects of health, wealth, and wages on labour supply and retirement behaviour". *Review of Economic Studies*, 72 , 395-427

[25] French, Eric and John Bailey Jones (2011): "The Effects of Health Insurance and Self-Insurance on Retirement Behavior," in *Econometrica*, vol. 79, issue 3, 693-732.

[26] Gallipoli, Giovanni and Laura Turner (2011): "Social Security, Endogenous Retirement, and Intrahousehold Cooperation," working paper, Univ of British Columbia.

[27] Gauthier, Anne H. (2007) "The impact of family policies on fertility in industrialized countries: a review of the literature." in *Population research and policy review* vol. 26, issue 3, 323-346.

[28] Gomes, Francisco and Alexander Michaelides (2005): "Optimal Life-Cycle Asset Allocation: Understanding the Empirical Evidence," in *The Journal of Finance*, Vol. 60, No. 2, 869-904.

[29] Groneck, Max and Johanna Wallenius (2021): "It sucks to be single! Marital status and redistribution of social security," in *The Economic Journal*, 327-371.

[30] Gustman, Alan L. and Thomas L. Steinmeier (1985): "The 1983 Social Security Reforms and Labor Supply Adjustments of Older Individuals in the Long Run," in *Journal of Labor Economics*, Vol. 3, No. 2, 237-253.

[31] Gustman, Alan L. and Thomas L. Steinmeier (1986): "A structural retirement model" in *Econometrica*, 54, 555-584

[32] Gustman, Alan L. and Thomas L. Steinmeier (2000): "Retirement in Dual-Career Families: A Structural Model," in *Journal of Labor Economics*, vol. 18, no 3, 503-545.

[33] Gustman Steinmeier (2002): "Social Security, pensions and retirement behaviour within the family." Journal of Applied Econometrics, 19, 723-737.

[34] Hansen, L. P. (1985): "Large Sample Properties of Generalized Method of Moments Estimators," *Econometrica,* 50, 1029-1054.

@articleheckman1990empirical, title=The empirical content of the Roy model, author=Heckman, James J and Honore, Bo E, journal=Econometrica: Journal of the Econometric Society, pages=1121–1149, year=1990, publisher=JSTOR

[35] Heckman, J.J. and B. Singer (1984). "A method for minimizing the impact of distributional assumptions in econometric models for duration data". *Econometrica* 52: 271-320.

[36] Huggett, Mark, and Gustavo Ventura (1999). "On the distributional effects of social security reform." Review of Economic Dynamics 2.3: 498-531.

[37] James, Estelle, Alejandra Cox Edwards, and Rebeca Wong (2003), The Gender Impact of Pension Reform in *Journal of Pension Economics and Finance* 2(2).

[38] Joubert, Clement (2015): "Pension design with a large informal labor market: Evidence from Chile." International Economic Review 56.2 (2015): 673-694.

[39] Joubert, Clement (2010): *Dynamic labor supply and savings incentives under a privatized pension system: evidence from Chile*, Dissertation, University of Pennsylvania.

[40] Kaygysez, Remzil (2015). "Social security and two-earner households. ". *Journal of Economic Dynamics and Control*, 59, pp. 163-178.

[41] Keane, M. P. and K. I. Wolpin (1994). "The solution and estimation of discrete choice dynamic programming models by simulation: Monte Carlo evidence". *Review of Economics and Statistics*: 648-672.

[42] Keane, M. P. and K. I. Wolpin (1997). "The career decisions of young men". *Journal of Political Economy* 105: 473-522.

[43] Kotlikoff, Laurence J., Kent Smetters, and Jan Walliser (1999) "Privatizing social security in the United Statescomparing the options." Review of Economic Dynamics 2.3: 532-574.

[44] Krasnokutskaya, Elena and Li, Yiyang and Petra E Todd (2018). "Product choice under government regulation: the case of Chile's privatized pension system", in *International Economic Review*, 59:4, 1747-1783.

[45] Laroque, Guy, and Bernard Salani (2014) "Identifying the response of fertility to financial incentives", in *Journal of Applied Econometrics* vol. 29, issue 2, 314-332.

[46] Maloney, William (1999): "Does Informality Imply Segmentation in Urban Labor Markets? Evidence from Sectoral Transitions in Mexico," in *The World Bank Economic Review*, Vol. 13, No. 2, 275-302.

[47] McKiernan, Kathleen (2018). "Welfare Impact of Social Security Reform: The Case of Chile in 1981." 2018 Meeting Papers. No. 253. Society for Economic Dynamics.

[48] Ministerio Trabajo y Previsión Social, Encuesta EPS

[49] Mitchell, Olivia S. and Gary S. Fields (1984): The Economics of Retirement Behavior, *Journal of Labor Economics* , Vol. 2, No. 1, pp. 84-105

[50] Nishiyama, Shinichi, and Kent Smetters (2007). "Does social security privatization produce efficiency gains?." The Quarterly Journal of Economics 122.4: 1677-1719.

[51] Nishiyama, Shinichi (2019): "The joint labor supply decision of married couples and the US Social Security pension system," in *Review of Economic Dynamics*, 31, 277-304.

[52] ODea, Cormac (2018). "Insurance, efficiency and the design of public pensions." 2018 Meeting Papers. No. 1037. Society for Economic Dynamics.

[53] Packard, Truman (2001): Pooling, savings, and prevention - mitigating the risk of old age poverty in Chile (English), *Policy, Research working paper*; no. WPS 2849. Washington, DC: World Bank. http://documents.worldbank.org/curated/en/459611468770358823/Pooling-savings-and-prevention-mitigating-the-risk-of-old-age-poverty-in-Chile

[54] Rust, John and Christopher Phelan (1997): "How Social Security and Medicare Affect Retirement Behavior in a World of Incomplete Markets," in *Econometrica*, Vol. 65, No. 4, 781-831.

[55] Sánchez-Marcos, V. and C. Bethencourt (2018). "The effect of public pensions on womens labor market participation over a full life cycle", *Quantitative Economics*, vol. 9(2), pp. 70733.

[56] Stock, James H. and Wise, David A. (1990): "Pensions, the option value of work and retirement" in *Econometrica* 58, 1151-1180

[57] Turner L., Gallipoli G., 2011."Social Security, Endogenous Retirement, and Intrahousehold Cooperation" - 2011 Meeting Papers - ideas.repec.org

[58] Van der Klaauw, Wilbert and Kenneth I. Wolpin (2008): "Social security and the retirement and savings behavior of low-income households," in *Journal of Econometrics*, 145, 21-42.

[59] Todd Petra E. and Kenneth I. Wolpin (2006). "Assessing the Impact of a School Subsidy Program in Mexico: Using a Social Experiment to Validate a Dynamic Behavioral Model of Child Schooling and Fertility," *American Economic Review*, vol. 96(5), 1384-1417.

9 Tables

	EPS respondents†		Estimation sample	
	N	Mean	N	Mean
Marital Status (%)††				
Married	9950	65.9	6109	67.5
Single Women	9950	21.8	6109	20.9
Single Men	9950	12.2	6109	11.7
Fraction Working (%)				
Women	8995	34.4	5482	31.9
Men	8115	74.1	4843	73.5
Formal Sector Employment (%)†††				
Women	3423	54.1	1916	52.2
Men	5978	56.5	3540	56.0
Age (yrs.)				
Women	9504	51.2	5474	50.9
Men	8452	52.2	4831	51.5
Schooling (yrs.)				
Women	9498	8.5	5474	8.2
Men	8443	8.9	4831	8.5
Number of children	9952	2.9	6109	3.0

† The EPS (*Encuesta de Protección Social*) sample is representative of the Chilean population in 2006. The entries in the table considers only individuals over age 35, in year 2004.
†† Cohabiting couples are also included in the "married" category.
††† The percentage of men and women in formal sector employment is taken among working individuals.

Table 1: Summary Statistics - Household Demographics and Labor Supply

	EPS respondents†					Estimation sample				
	N	p10	p25	p50	p75	N	p10	p25	p50	p75
Annual Earnings††										
Women	2218	0.5	1.0	1.6	3.0	1284	0.4	0.8	1.6	2.4
Men	3528	0.8	1.6	2.4	4.0	1944	0.7	1.4	2.2	3.6
Pension assets††										
Women	5323	0.0	0.0	0.0	0.6	3358	0.0	0.0	0.0	0.5
Men	4997	0.0	0.0	1.4	8.1	2751	0.0	0.0	1.4	7.3
Household assets††	8583	0.0	2.5	7.0	15.0	6109	0.0	2.3	6.7	15.0

† The EPS (*Encuesta de Proteccin Social*) sample is representative of the Chilean population in 2006. This table considers only individuals over age 35, in year 2004
†† Assets and earnings are reported in millions of Chilean Pesos.

Table 2: Summary Statistics - Earnings and assets

Name	**Symbol**	**Estimate**	***Std. errors***
CRRA coefficient	$1-\eta$	-0.17E+01***	*0.80E-01*
MUc - Stock of children (female)	ν_0^f	0.20E-02	*0.89E-02*
MUc - Stock of children (male)	ν_0^m	0.23E-01	*0.20E-01*
MUc - Leisure (female)	ν_1^f	-0.31E+01***	*0.22E+00*
MUc - Leisure (male)	ν_1^m	-0.50E+01***	*0.73E+00*
Ul - female type 1	δ_I^f	0.31E-03	*0.14E-02*
Ul - female type 2	δ_I^f	0.33E-03***	*0.12E-03*
Ul - female type 3	δ_I^f	0.98E-05	*0.36E-04*
Ul - female type 4	δ_I^f	0.31E-03	*0.40E-03*
Ul - male type 1	δ_I^m	0.12E+02**	*0.51E+01*
Ul - male type 2	δ_I^m	0.19E-04	*0.35E-04*
Ul - male type 3	δ_I^m	0.24E-05	*0.25E-05*
Ul - male type 4	δ_I^m	0.51E+01***	*0.18E+01*
Ul - part-time	δ_p^f	0.62E-01	*0.11E+00*
Ul - number of children	δ_n^f	0.19E+00	*0.27E+00*
Ul - married	δ_m^f	0.50E+01***	*0.81E+00*
Ul - LRA (male)	δ_C^m	0.59E+01***	*0.43E+00*
Ul - LRA (female)	δ_C^f	0.20E+00	*0.17E+01*
Discount rate	β	0.10E+01***	*0.18E-01*
Switching costs (male)	Φ_s^m	0.58E+02***	*0.14E+02*
Switching costs (female)	Φ_s^f	0.19E+02***	*0.34E+01*
Entry costs (male)	Φ_r^m	0.64E+02***	*0.14E+02*
Entry costs (female)	Φ_r^f	0.91E+02***	*0.12E+02*
Non-pecuniary benefits informal sector (female type 1)	Φ_2^f	-0.69E+01***	*0.24E+01*
Non-pecuniary benefits informal sector (female type 2)	Φ_2^f	-0.10E+02**	*0.41E+01*
Non-pecuniary benefits informal sector (female type 3)	Φ_2^f	-0.98E+01*	*0.58E+01*
Non-pecuniary benefits informal sector (female type 4)	Φ_2^f	0.45E+01***	*0.12E+01*
Non-pecuniary benefits informal sector (male type 1)	Φ_2^m	0.14E+03***	*0.51E+02*
Non-pecuniary benefits informal sector (male type 2)	Φ_2^m	-0.75E+01	*0.68E+01*
Non-pecuniary benefits informal sector (male type 3)	Φ_2^m	0.43E+01***	*0.98E+00*
Non-pecuniary benefits informal sector (male type 4)	Φ_2^m	0.95E+03	*0.78E+03*
Consumption floor	C_{min}	0.50E-01	*0.38E+01*
Ul shock variance	σ_H^m	0.20E+02***	*0.17E+01*

Model parameters are described in section 4
LRA: Legal Retirement Age
Ul : Utility of leisure
MUc : Marginal Utility of consumption
CRRA : Coefficient of Relative Risk Aversion

Table 3: Simulated Method of Moments Estimates - Preferences

Name	**Symbol**	**Estimate**	***Std. errors***
Log formal earnings (male type 1) - constant	θ^m_{0F}	0.40E+01***	*0.14E+00*
Log formal earnings (male type 2) - constant	θ^m_{0F}	0.21E+01***	*0.20E+00*
Log formal earnings (male type 3) - constant	θ^m_{0F}	0.45E+01***	*0.28E+00*
Log formal earnings (male type 4) - constant	θ^m_{0F}	0.88E+00***	*0.11E+00*
Log formal earnings (male) - schooling	θ^m_{1F}	0.32E-01***	*0.20E-02*
Log formal earnings (male) - experience	θ^m_{3F}	0.13E-01***	*0.51E-03*
Log formal earnings (male) - quadratic exp.	θ^m_{4F}	-0.85E-03	*0.16E+00*
Log formal earnings (male) - quadratic school.	θ^m_{2F}	0.50E-02**	*0.25E-02*
Log informal earnings (male type 1) - constant	θ^m_{0I}	0.22E+01***	*0.25E+00*
Log informal earnings (male type 2) - constant	θ^m_{0I}	0.17E+01***	*0.64E+00*
Log informal earnings (male type 3) - constant	θ^m_{0I}	0.45E+01***	*0.53E+00*
Log informal earnings (male type 4) - constant	θ^m_{0I}	0.29E+01***	*0.16E+00*
Log informal earnings (male) - schooling	θ^m_{1I}	0.15E+00***	*0.85E-02*
Log informal earnings (male) - experience	θ^m_{3I}	0.98E-04***	*0.13E-04*
Log informal earnings (male) - quadratic exp.	θ^m_{4I}	0.00E+00	*0.28E+02*
Log informal earnings (male) - quadratic school.	θ^m_{2I}	0.00E+00	*0.10E+02*
Log formal earnings (female type 1) - constant	θ^m_{0F}	0.36E+00***	*0.23E-01*
Log formal earnings (female type 2) - constant	θ^m_{0F}	0.85E+00***	*0.95E-01*
Log formal earnings (female type 3) - constant	θ^m_{0F}	0.33E+00***	*0.40E-01*
Log formal earnings (female type 4) - constant	θ^m_{0F}	0.61E+00***	*0.77E-01*
Log formal earnings (female) - schooling	θ^f_{1F}	0.51E-04	*0.73E-04*
Log formal earnings (female) - experience	θ^f_{3F}	0.14E-01***	*0.15E-02*
Log formal earnings (female) - quadratic exp.	θ^f_{4F}	-0.63E-04	*0.51E+04*
Log formal earnings (female) - quadratic school.	θ^f_{2F}	0.94E-02	*0.23E+04*
Log informal earnings (female type 1) - constant	θ^f_{0I}	0.31E+00***	*0.40E-01*
Log informal earnings (female type 2) - constant	θ^f_{0I}	0.31E+00**	*0.13E+00*
Log informal earnings (female type 3) - constant	θ^f_{0I}	0.61E+00*	*0.34E+00*
Log informal earnings (female type 4) - constant	θ^f_{0I}	0.12E+01***	*0.74E-01*
Log informal earnings (female) - schooling	θ^f_{1I}	0.49E-01***	*0.79E-02*
Log informal earnings (female) - experience	θ^f_{3I}	0.21E-01***	*0.35E-02*
Log informal earnings (female) - quadratic exp.	θ^f_{4I}	0.00E+00	*0.52E+01*
Log informal earnings (female) - quadratic school.	θ^f_{2I}	0.16E-03	*0.99E+02*
Formal offer probability (male) - constant	γ^m_0	-0.27E+00***	*0.71E-01*
Formal offer probability (male) - schooling	γ^m_2	-0.72E+00***	*0.10E+00*
Formal offer probability (male) - formal	γ^m_1	0.35E+01***	*0.46E+00*
Formal offer probability (male) - age	γ^m_3	0.20E+00***	*0.29E-01*
Formal offer probability (female) - constant	γ^f_0	-0.84E+01***	*0.32E+01*
Formal offer probability (female) - schooling	γ^f_2	0.50E+01***	*0.55E+00*
Formal offer probability (female) - formal	γ^f_1	-0.10E+02***	*0.36E+01*
Formal offer probability (female) - age	γ^f_3	-0.52E+00***	*0.96E-01*
Formal Earnings variance (male)	σ^m_F	0.12E-01	*0.91E+01*
Informal Earnings variance (male)	σ^m_I	0.34E+00	*0.46E+01*
Formal Earnings variance (female)	σ^f_F	0.51E+00***	*0.51E-01*
Informal Earnings variance (female)	σ^f_I	0.67E+00***	*0.77E-01*

Model parameters are described in section 4

Table 4: Simulated Method of Moments Estimates - Earnings

	Men				Women			
	Old system	2008 reform	Δ	%Δ	Old system	2008 reform	Δ	%Δ
By Age								
50-54	0.83	0.84	0.01	2%	0.69	0.68	-0.01	-1%
55-59	0.79	0.84	0.04	6%	0.54	0.53	-0.01	-1%
60-64	0.76	0.73	-0.03	-4%	0.36	0.34	-0.02	-7%
65-69	0.37	0.32	-0.05	-12%	0.11	0.09	-0.02	-22%
70-74	0.25	0.23	-0.02	-9%	0.03	0.03	0.00	-12%
By Schooling								
No HS	0.58	0.60	0.01	2%	0.20	0.19	-0.02	-9%
Some HS	0.74	0.74	0.00	0%	0.49	0.49	0.00	0%
HS Graduate	0.76	0.73	-0.02	-3%	0.73	0.71	-0.02	-2%
College Graduate	0.67	0.64	-0.03	-4%	0.84	0.82	-0.02	-2%
By Marital Status								
Single	0.64	0.68	0.04	7%	0.50	0.50	0.00	0%
Married	0.68	0.65	-0.03	-5%	0.36	0.33	-0.03	-8%

Entries correspond to the fraction working in years 2009-2015 among individuals aged 50-74 in each subgroup, simulated under the 2008 reform and under the old system. Columns 3-4 and 7-8 can therefore be interpreted as isolating the behavioral changes caused by the reform.

Table 5: Short-term Impact of the 2008 Reform on Labor Force Participation

	Men				Women			
	Old system	2008 reform	Δ	%Δ	Old system	2008 reform	Δ	%Δ
By Age								
50-54	0.40	0.45	0.05	12%	0.39	0.38	-0.01	-2%
55-59	0.40	0.41	0.01	4%	0.34	0.34	0.01	2%
60-64	0.34	0.29	-0.04	-13%	0.21	0.20	-0.01	-3%
By Schooling								
No HS	0.33	0.38	0.05	14%	0.00	0.00	0.00	-36%
Some HS	0.45	0.44	-0.01	-3%	0.36	0.36	0.00	0%
HS Graduate	0.44	0.42	-0.02	-4%	0.74	0.72	-0.02	-2%
College Graduate	0.25	0.22	-0.03	-13%	0.72	0.74	0.02	3%
By Marital Status								
Single	0.23	0.31	0.08	33%	0.36	0.36	0.00	-1%
Married	0.51	0.47	-0.04	-9%	0.28	0.28	0.00	-1%

Entries correspond to the fraction working formally (unconditional on working) in years 2009-2015 among individuals aged 50-64 in each subgroup, simulated under the 2008 reform and under the old system. Columns 3-4 and 7-8 can therefore be interpreted as isolating the behavioral changes caused by the reform.
† We only analyze the impact on formality until age 64, because after age 65, contributing to the pension system becomes optional for both genders, and the formal-informal distinction becomes less relevant for our purposes.

Table 6: Short-term Impact of the 2008 Reform on Formal Employment

		0	0bis	1	2	3	4	5	6	7	8	9
Total Gender Gap		44%	27%	23%	12%	20%	22%	20%	27%	25%	23%	4%
By Terciles												
	Tercile 1	87%	80%	6%	2%	1%	2%	5%	15%	6%	7%	-3%
	Tercile 2	45%	46%	17%	13%	14%	16%	16%	23%	16%	8%	10%
	Tercile 3	40%	14%	30%	14%	29%	29%	27%	32%	33%	33%	3%
By Schooling												
	No HS	49%	45%	22%	18%	19%	20%	20%	28%	22%	16%	13%
	Some HS	57%	46%	30%	22%	27%	28%	28%	34%	31%	34%	15%
	HS Grad	31%	-1%	17%	-3%	14%	16%	13%	20%	19%	20%	-16%
	College Grad	22%	-19%	12%	-20%	10%	12%	7%	14%	18%	13%	-34%
By Yrs. Of Formal Exp.												
	Less than 10 years	17%	12%	0%	-5%	-5%	-2%	-2%	8%	-2%	-1%	-10%
	11-20 years	24%	-8%	15%	2%	12%	13%	12%	19%	10%	19%	-10%
	20+ years	7%	-33%	0%	-29%	-1%	0%	-6%	2%	7%	-1%	-42%
By marital status												
	single	28%	4%	12%	0%	10%	13%	10%	16%	15%	13%	-7%
	married	64%	52%	35%	26%	32%	33%	33%	40%	36%	34%	17%
By Number of Children												
	No Children	-10%	-51%	7%	-11%	2%	7%	4%	7%	0%	2%	-19%
	1-2 Children	25%	-2%	10%	-8%	7%	9%	6%	12%	12%	9%	-18%
	3 or more Children	60%	50%	32%	25%	30%	30%	30%	37%	34%	33%	18%

Entries correspond the difference between average pension benefits among men and women in each subgroup divided by the average pension benefits among men (therefore, a positive number represents a relative female deficit). For example, entries under tercile one correspond to the percentage difference between the average pension benefit in the bottom third of the male pension benefit distribution, and the average pension benefit in the bottom third of the female pension benefit distribution.
The simulations results in this table consider 11 scenarios, described in section 7:
0 - Old System
0bis - Old System with gender neutral rules
1 - 2008 reform
2 - Equal retirement age
3 - Contribution split
4 - Extra spousal contribution
5 - Gender neutral life tables
6 - Reform without child bonus
7 - Reform without divorce rule
8 - Reform with full claw-back
9 - All features

Table 7: The gender pension gap at age 65 under different policies

		0	0bis	1	2	3	4	5	6	7	8	9
Pre-Retirement LFP												
	Men	99.8	100.0	100.0	100.5	98.9	97.8	99.9	100.2	98.0	100.1	98.3
	Women	100.3	101.4	100.0	114.2	100.7	100.5	98.8	99.6	98.7	100.3	113.2
Years Contributed												
	Men	100.2	100.3	100.0	100.6	100.5	99.4	100.0	100.0	98.6	100.0	98.6
	Women	100.3	99.8	100.0	101.0	100.0	100.0	99.7	99.7	99.7	100.4	100.8
Pension Assets												
	Men	102.9	93.6	100.0	100.3	96.7	100.3	100.0	99.2	102.1	100.0	99.9
	Women	83.5	107.6	100.0	138.1	102.6	105.1	88.1	83.0	100.1	100.5	134.8
Household Assets		100.9	93.7	100.0	98.7	98.9	99.3	100.4	99.6	94.6	102.8	100.2
Household Cons.		91.5	90.1	100.0	98.6	98.9	99.3	100.3	98.8	99.9	96.7	99.0
System Costs		52.6	49.8	100.0	98.6	100.7	99.8	99.6	91.8	100.0	85.8	97.1

Entries correspond to the average value for each outcome in scenario, 20 years after the reform. Scenario 1 (the 2008 reform) is normalized to 100.
LFP (Labor Force Participation) is measured among individuals close to retirement (aged 60-65). Years contributed and Assets are measured among individuals recently retired (65-70). Household consumption and system Costs, which correspond to government spending in pension benefits (including the child benefit), are computed among all retirees.
The simulations results in this table consider 11 scenarios, described in section 7:
0 - Old System
0bis - Old System with gender neutral rules
1 - 2008 reform
2 - Equal retirement age
3 - Contribution split
4 - Extra spousal contribution
5 - Gender neutral life tables
6 - Reform without child bonus
7 - Reform without divorce rule
8 - Reform with full claw-back
9 - All features

Table 8: Behavioral impacts of different policies

10 Figures

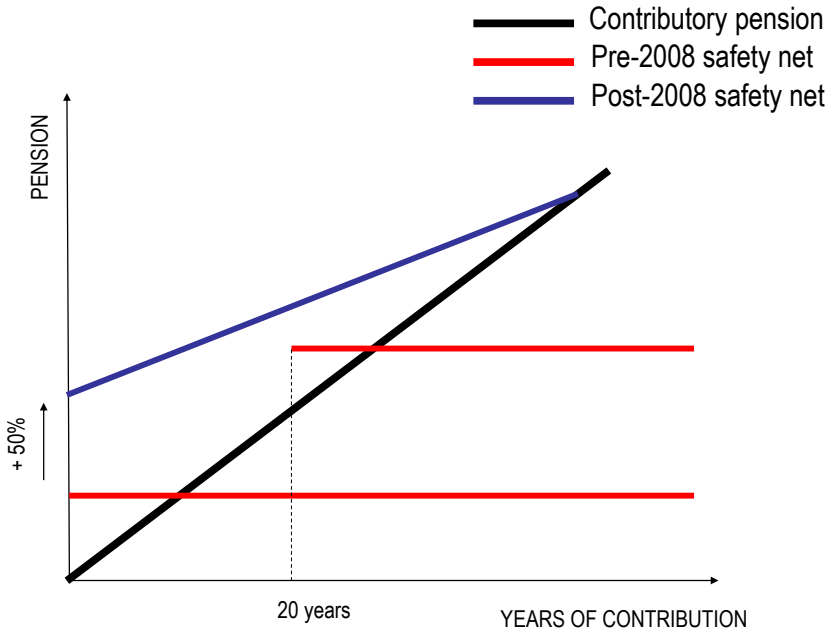

Figure 1: Pension benefit levels pre- and post- reform

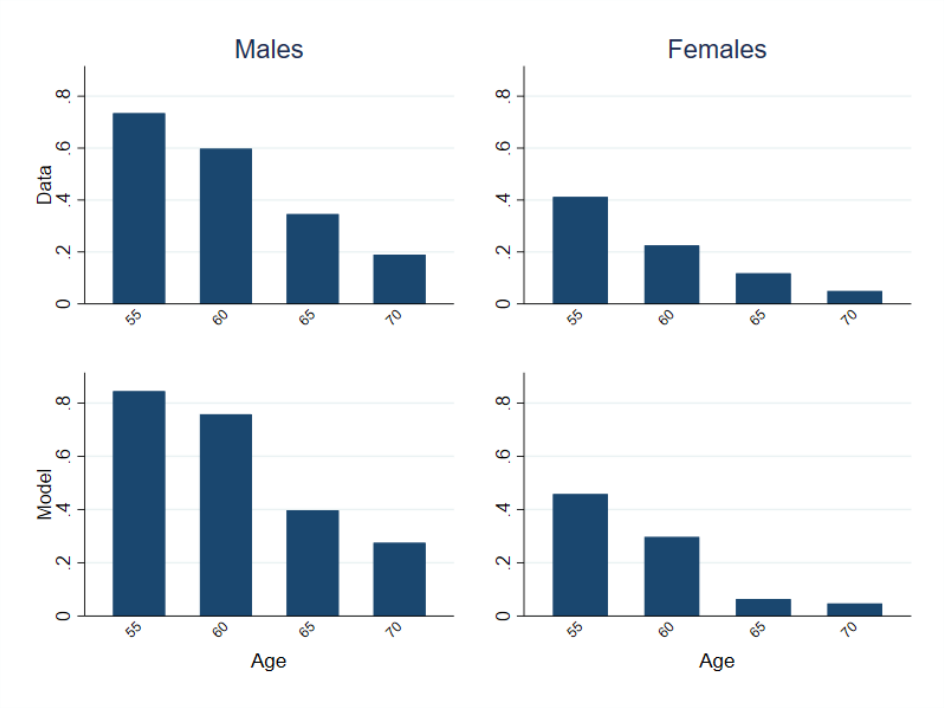

Figure 2: Model Fit - Labor force participation around retirement

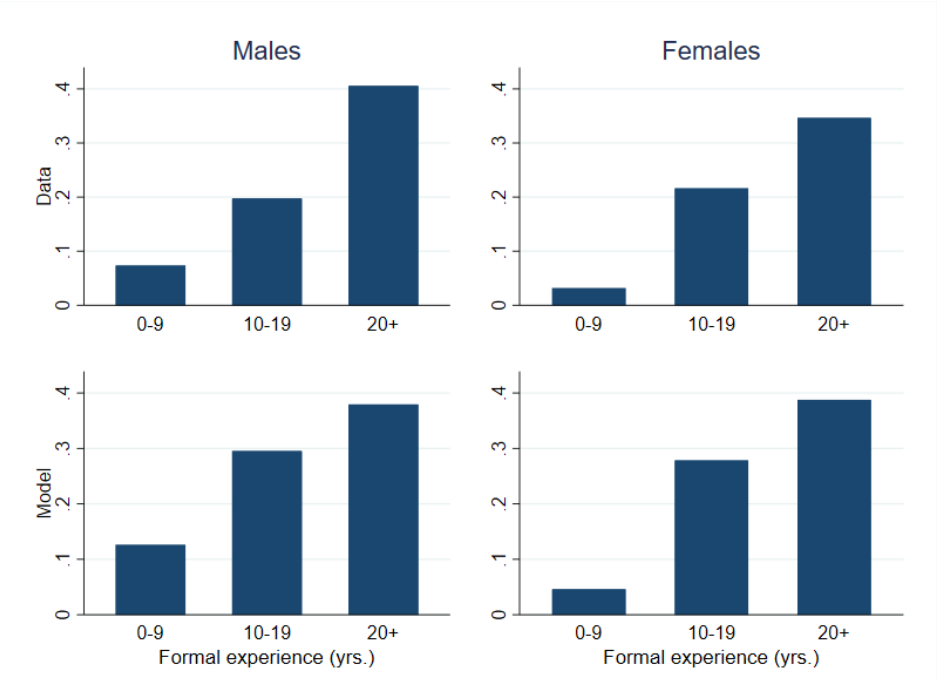

Figure 3: Model Fit - Formal sector participation by years of formal experience

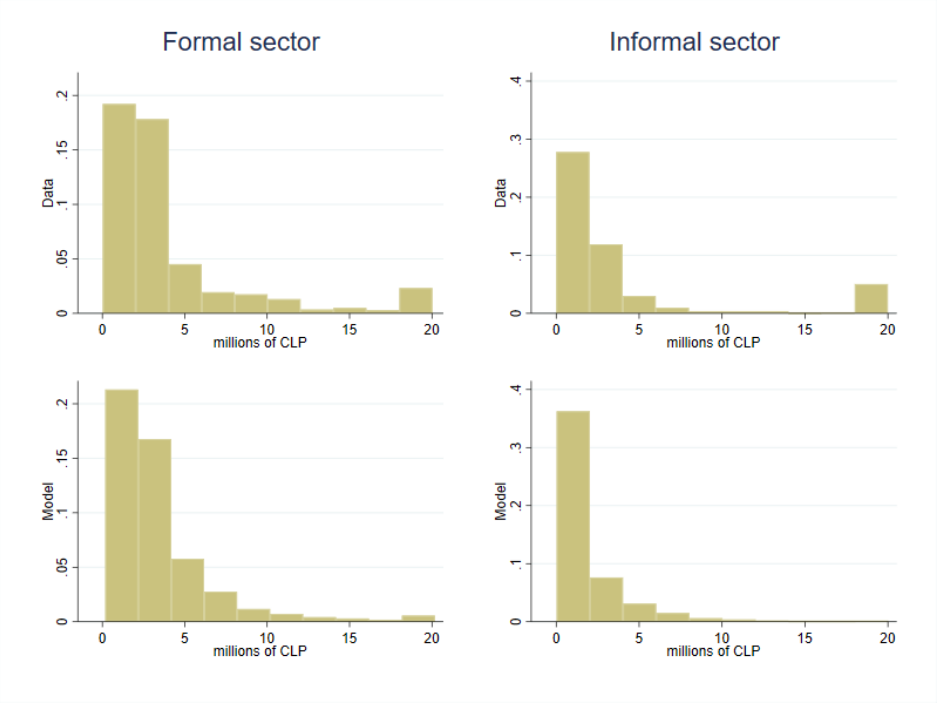

Figure 4: Model Fit - Distribution of earnings by sector

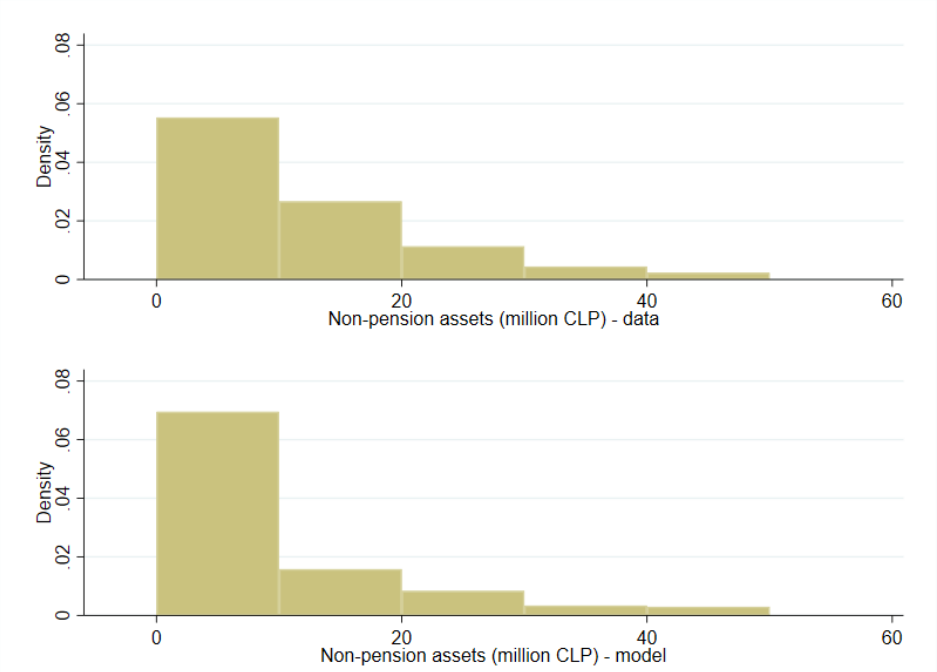

Figure 5: Model Fit - Distribution of non-pension wealth

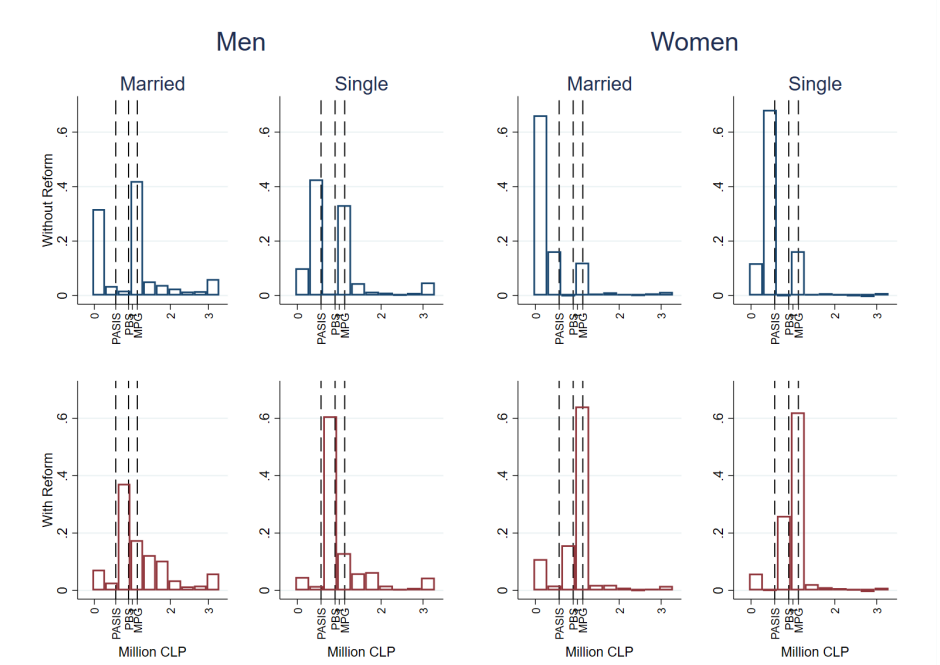

Figure 6: Simulated pension benefits with and without the 2008 reform, by marital status

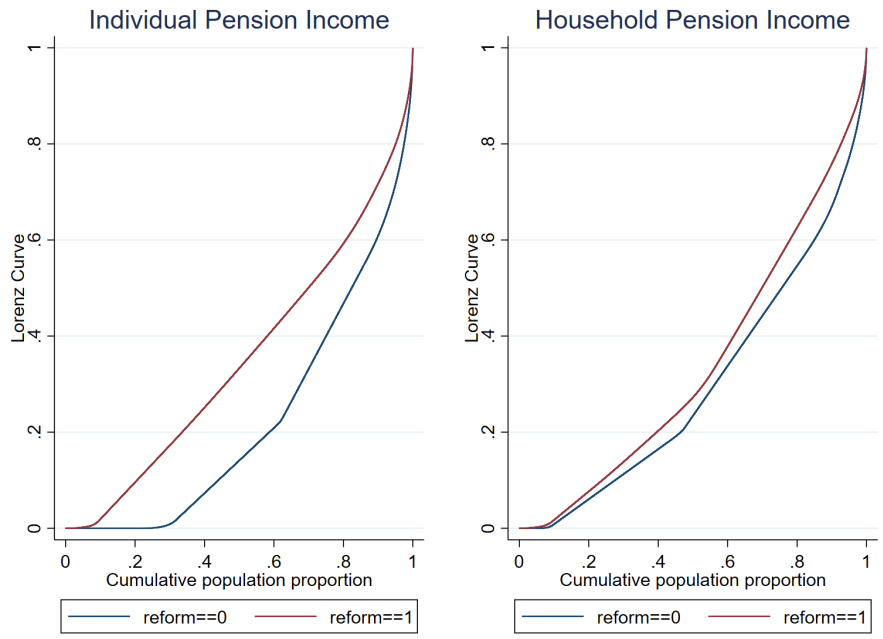

Figure 7: Impact of the 2008 reform on pension inequality at the individual and household level

A Solution and Estimation Method

A.1 Solution Method

Model solution proceeds as follows. At age $t_D - 1$, a household decides on labor force participation and consumption, which together imply a level of savings, to maximize the weighted sum of current and future period utilities, denoted by $V_{t_D-1}(\Omega_{t_D-1}; \tilde{\epsilon}_{t_D-1})$, where the state vector is divided into a deterministic component containing the elements that are not random at the beginning of period $t_D - 1$, Ω_{t_D-1}, and a shock component containing the vector of random earnings and preference shocks drawn at $t_D - 1$, $\tilde{\epsilon}_{t_D-1}$.

For any given value of the deterministic and shock components of the state vector, optimal consumption is obtained by comparing utility on a grid of possible consumption levels, for each of the possible choices of husbands' and wives' labor sectors. The labor decision and associated optimal consumption that maximizes total utility is chosen for that value of the state vector.

At any deterministic state point, the expected value of V_{t_D-1} is obtained by Monte Carlo integration, that is, by taking draws from the shock vector distribution and averaging to obtain $EV_{t_D-1}(\Omega_{t_D-1})$. This expectation is calculated at a subset of the deterministic state points and the function is approximated for all other state points by a polynomial regression following an approximation method developed by Keane and Wolpin (1994, 1997).[51] We denote this function as $Emax_{t_D-1}(.)$.

This procedure is repeated at age $t_D - 2$. Using the recursive formulation of the value function, substituting the $Emax_{t_D-1}(.)$ function for the future component, the optimal decision is computed. Monte Carlo integration over the shock vector at $t_D - 2$ provides $EV_{t_D-2}(\Omega_{t_D-2})$ for a given deterministic state point. A polynomial regression over a subset of the state points again provides an approximation to the function, denoted by $Emax_{t_D-2}$. Repeating the procedure back to the initial age provides the $Emax$ polynomial approximation at each age. The set of $Emax_t$ functions fully describe the solution to the optimization problem.

[51] The approximation uses spline functions in pension and non-pension wealth interacted with household characteristics - marital status, schooling, current labor supply - to capture the incentives embedded in the pension rules. We used 10 draws for the Monte Carlo integration and 3000 state points for the approximation.

A.2 Estimation Method

Tables B1-B5 show the list of moments used to estimate the model. There are 259 moments (M) and 109 estimated model parameters (K). The moments pertain to labor force participation, mean earnings, earnings dispersion, first differences in earnings, labor force sector status (formal or informal and year-to-year transitions), and household assets for different subgroups that are distinguished by age, gender, marital status, schooling level, and labor force status (for the earnings moments). The estimated parameter values are reported in tables 3-4 and B6 with standard errors in italics. The fertility logit parameters were estimated separately and are presented in Table B8.

We next describe how standard errors are obtained. Denote by x_i^m an outcome measure of individual i, $i \in 1..N$, pertaining to the mth moment, $m = 1..M$. $\hat{x}_{irk}^m$ is the same outcome measure under simulation r when the individual is type k. The Method of Simulated Moments estimator that we use is defined as:

$$\hat{\theta}_N = \arg\max_{\theta\in\Theta} \left[\frac{1}{N}\sum_{i=1}^{n}\left[x_i^m D_i^m \frac{N}{N^m} - \left(\frac{1}{R}\sum_{r=1}^{R}\sum_{k=1}^{K}\hat{x}_{irk}^m(\theta)\hat{D}_{irk}^m(\theta)\frac{N}{N^m}Pr(k|\Omega)\right)\right]\right]'_{1\times M} W^{-1}$$
$$\left[\frac{1}{N}\sum_{i=1}^{n}\left[x_i^m D_i^m \frac{N}{N^m} - \left(\frac{1}{R}\sum_{r=1}^{R}\sum_{k=1}^{K}\hat{x}_{irk}^m(\theta)\hat{D}_{irk}^m(\theta)\frac{N}{N^m}Pr(k|\Omega)\right)\right]\right]_{M\times 1}$$

where D_i^m is an indicator for whether observation i is included in calculating moment condition m, $\hat{D}_{irk}^m$ is an indicator for whether the observation is included in moment m under simulation r when the individual is type k, and $N^m = \sum_{i=1}^{n} D_i^m$. The sum over k integrates over the unobserved types. For example, suppose the moment pertains to the wages of males in some age range who are working. In that case, $D_i^m = 1$ for males in a given age range who are working. $\hat{D}_{irk}^m = 1$ for males in that age range who are simulated to be working. The weighting matrix W is an M by M diagonal matrix with the m^{th} diagonal elements equal to the sample variance of x_i^m.[52] Integrating over the unobservables, k, and assuming that $R \to \infty$ so that the simulation error goes to zero and the term in parentheses converges (uniformly in θ) to the limit, we get

$$\mu_i^m(\theta) = E(\hat{x}_{irk}^m(\theta)|\hat{D}_i^m(\theta) = 1)Pr(\hat{D}_i^m(\theta) = 1)\frac{N}{N^m}. \quad (1)$$

[52] We do not use the optimal weighting matrix (the inverse of the variance of the moments), because of difficulties in inverting the matrix during the course of the optimization. However, the efficiency cost of not using the optimal weighting matrix is probably not that great. Altonji and Segal (1996) provide Monte-Carlo evidence of small-sample bias when the optimal weighting matrix is used.

Defining

$$\mu_i^m = x_i^m D_i^m \frac{N}{N^m}, \tag{2}$$

we can rewrite the objective function as:

$$\hat{\theta}_N = \arg\max_{\theta \in \Theta} \left[\frac{1}{N} \sum_{i=1}^{n} (\mu_i^m - \mu_i^m(\theta)) \right]'_{1\times M} W^{-1} \left[\frac{1}{N} \sum_{i=1}^{n} (\mu_i^m - \mu_i^m(\theta)) \right]_{M\times 1}$$

Taking first order conditions with respect to θ yields [53] :

$$\left[\frac{1}{N} \sum_{i\in S} \frac{\delta \mu_i^m}{\delta \theta}|_{\hat{\theta}_N} \right]' W^{-1} \left[\frac{1}{N} \sum_{i\in S} (\mu_i^m - \mu_i^m(\hat{\theta}_N)) \right] = 0 \tag{3}$$

A Taylor expansion of $\mu_i^m(\hat{\theta}_N)$ around the true parameter vector θ_0 yields:

$$\mu_i^m(\hat{\theta_N}) = \mu_i^m(\theta_0) + \frac{\delta \mu_i^m}{\delta \theta}|_{\theta^*} \cdot (\hat{\theta}_N - \theta_0) \tag{4}$$

for some θ^* between $\hat{\theta}_N$ and θ_0.

We obtain after rearranging:

$$\begin{aligned} \sqrt{N}(\hat{\theta}_N - \theta_0) \quad = \quad & \left[\left[\frac{1}{N} \sum_{i\in S} \frac{\delta \mu_i^m}{\delta \theta}|_{\hat{\theta}_N} \right]' W^{-1} \left[\frac{1}{N} \sum_{i\in S} \frac{\delta \mu_i^m}{\delta \theta}|_{\hat{\theta}^*} \right] \right]^{-1} \\ & \times \left[\frac{1}{N} \sum_{i\in S} \frac{\delta \mu_i^m}{\delta \theta}|_{\hat{\theta}_N} \right]' W^{-1} \left[\frac{1}{\sqrt{N}} \sum_{i\in S} (\mu_i^m - \mu^m(\theta_0)) \right]. \end{aligned}$$

Following Hansen (1981), we can obtain the estimator's asymptotic variance-covariance matrix as:

$$Asy.Var(\hat{\theta}_N) = \left(D_0' W^{-1} D_0\right)^{-1} D_0' W^{-1} V_0 W^{-1} D_0 \left(D_0' W^{-1} D_0\right)^{-1\prime},$$

where $D_0 = E\left[\frac{\delta \mu^m}{\delta \theta}|_{\theta_0}\right]$, $V_0 = E\left(\left[\mu_i^m - \mu_i^m(\theta_0)\right]\left[\mu_j^m - \mu_j^m(\theta_0)\right]\right)'$.

In computing the standard errors, D_0 is estimated using numerical derivatives of the model's moments at the estimated vector of parameters, V_0 is approximated by the sample variance-covariance of $\left[x_j^m - \mu_j^m(\theta_0)\right]$ and W_0 is the diagonal matrix that contains the diagonal elements of V_0. The standard errors are corrected for the variance resulting from replacing the true model-implied moments by simulated moments.

[53] If the number of simulations $R \to \infty$, then the limiting objective is differentiable despite the original objective function not being differentiable.

B Supplementary Tables and Figures

Outcome			Conditions																	
			Age		Mar.		Fem.		Kids		Sch.		XP		Fo. XP		Assets	
	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+
LFP	1		51	55			0	0										
LFP	1		56	60			0	0										
LFP	1		61	65			0	0										
LFP	1		66	70			0	0										
LFP	1		71	75			0	0										
LFP	1		51	55	1	1	1	1										
LFP	1		56	60	1	1	1	1										
LFP	1		61	65	1	1	1	1										
LFP	1		66	70	1	1	1	1										
LFP	1		71	75	1	1	1	1										
LFP	1		51	55	0	0	1	1										
LFP	1		56	60	0	0	1	1										
LFP	1		61	65	0	0	1	1										
LFP	1		66	70	0	0	1	1										
LFP	1		71	75	0	0	1	1										
LFP	1		51	75			1	1					0	0				
LFP	1		51	75			1	1					0.5	5				
LFP	1		51	75			1	1					5.5	15				
LFP	1		51	75			1	1					16					
LFP	1		51	75			1	1			0	7						
LFP	1		51	75			1	1			8	11						
LFP	1		51	75			1	1			12	15						
LFP	1		51	75			1	1			16							
LFP	1		51	75			1	1	0	0								
LFP	1		51	75			1	1	1	0								
LFP	1		51	75			1	1	3	2								
LFP	1		51	75			1	1										
LFP	1		51	75			1	1									0	0
LFP	1		51	75			1	1									0.1	3
LFP	1		51	75			1	1									3.1	6
LFP	1		51	75			1	1									6.1	
LFP	2		51	75	1	1	1	1										
LFP	2		51	75	0	0	1	1										
Formal Sector	1	1	51	55			0	0										
Formal Sector	1	1	56	60			0	0										
Formal Sector	1	1	61	65			0	0										
Formal Sector	1	1	66	70			0	0										
Formal Sector	1	1	51	55			1	1										
Formal Sector	1	1	56	60			1	1										
Formal Sector	1	1	61	65			1	1										
Formal Sector	1	1	66	70			1	1										
Formal Sector	1	1	71	75			1	1										
Formal Sector	1	1	51	75			0	0			0	7						
Formal Sector	1	1	51	75			0	0			8	11						
Formal Sector	1	1	51	75			0	0			12	15						
Formal Sector	1	1	51	75			0	0			16							
Formal Sector	1	1	51	75			1	1			0	7						
Formal Sector	1	1	51	75			1	1			8	11						
Formal Sector	1	1	51	75			1	1			12	15						
Formal Sector	1	1	51	75			1	1			16							
Formal Sector	1	1	51	75			0	0							0	0		
Formal Sector	1	1	51	75			0	0							1	10		
Formal Sector	1	1	51	75			0	0							11			
Formal Sector	1	1	51	75			1	1							0	0		
Formal Sector	1	1	51	75			1	1							1	10		
Formal Sector	1	1	51	75			1	1							11			
Nb. of Earners	2	2	51	75	1	1												
Nb. of Earners	0	0	51	75	1	1												
Nb. Formal	2	2	51	75	1	1												
Nb. Formal	0	0	51	75	1	1												

LFP: Labor Force Participation (coded as 0, 1 or 2, where 2 denotes part-time work).
Formal Sector: Employment in the formal sector (coded as 1 or 0).
Nb. of Earners (Nb. Formal): Number of individuals working (working formally) in the household, defined as the husband and the wife selected in the estimation sample.
Mar.: Married or cohabiting.
Fem.: Female.
Kids: Number of children.
Sch.: Years of schooling.
XP: Work experience, in years.
Fo. XP: Work experience in the formal sector, in years.
Assets: Household assets, excluding pension accounts.
Moments are defined by an outcome variable and bounds (columns - and +) on that outcome variable and on conditioning variables. For example, the first moment corresponds to the fraction of individuals who work (LFP greater or equal to 1), among individuals aged 51 to 55, of male gender (Female equal to 0).

Table B1: List of moments: Labor Force Participation

Outcome			Conditions											
			Age		Fem.		LFP		FLFP		Lag. LFP		Lag. Fo.	
	-	+	-	+	-	+	-	+	-	+	-	+	-	+
Formal to Formal	1	1	51	75	1	1					1	1	1	1
Formal to Informal	1	1	51	75	1	1					1	1	1	1
Formal to Home	1	1	51	75	1	1					1	1	1	1
Informal to Formal	1	1	51	75	1	1					1	1	0	0
Informal to Informal	1	1	51	75	1	1					1	1	0	0
Informal to Home	1	1	51	75	1	1					1	1	0	0
Home to Formal	1	1	51	75	1	1					0	0		
Home to Informal	1	1	51	75	1	1					0	0		
Home to Home	1	1	51	75	1	1					0	0		
Formal to Formal	1	1	51	75	0	0					1	1	1	1
Formal to Informal	1	1	51	75	0	0					1	1	1	1
Formal to Home	1	1	51	75	0	0					1	1	1	1
Informal to Formal	1	1	51	75	0	0					1	1	0	0
Informal to Informal	1	1	51	75	0	0					1	1	0	0
Informal to Home	1	1	51	75	0	0					1	1	0	0
Home to Formal	1	1	51	75	0	0					0	0		
Home to Informal	1	1	51	75	0	0					0	0		
Home to Home	1	1	51	75	0	0					0	0		
$y_t - y_{t-1}$		-0.5	51	75			1		1	1	1	1	0	0
$y_t - y_{t-1}$	-0.499	0	51	75			1		1	1	1	1	0	0
$y_t - y_{t-1}$	1E-06	0.25	51	75			1		1	1	1	1	0	0
$y_t - y_{t-1}$	0.25	0.5	51	75			1		1	1	1	1	0	0
$y_t - y_{t-1}$	0.5	0.75	51	75			1		1	1	1	1	0	0
$y_t - y_{t-1}$	0.75	1	51	75			1		1	1	1	1	0	0
$y_t - y_{t-1}$	1		51	75			1		1	1	1	1	0	0
$y_t - y_{t-1}$		-0.5	51	75			1		0	0	1	1	1	1
$y_t - y_{t-1}$	-0.499	0	51	75			1		0	0	1	1	1	1
$y_t - y_{t-1}$	1E-06	0.25	51	75			1		0	0	1	1	1	1
$y_t - y_{t-1}$	0.25	0.5	51	75			1		0	0	1	1	1	1
$y_t - y_{t-1}$	0.5	0.75	51	75			1		0	0	1	1	1	1
$y_t - y_{t-1}$	0.75	1	51	75			1		0	0	1	1	1	1
$y_t - y_{t-1}$	1		51	75			1		0	0	1	1	1	1
$y_t - y_{t-1}$		-0.5	51	75			1		1	1	1	1	1	1
$y_t - y_{t-1}$	-0.499	0	51	75			1		1	1	1	1	1	1
$y_t - y_{t-1}$	1E-06	0.25	51	75			1		1	1	1	1	1	1
$y_t - y_{t-1}$	0.25	0.5	51	75			1		1	1	1	1	1	1
$y_t - y_{t-1}$	0.5	0.75	51	75			1		1	1	1	1	1	1
$y_t - y_{t-1}$	0.75	1	51	75			1		1	1	1	1	1	1
$y_t - y_{t-1}$	1		51	75			1		1	1	1	1	1	1
$y_t - y_{t-1}$		-0.5	51	75			1		0	0	1	1	0	0
$y_t - y_{t-1}$	-0.499	0	51	75			1		0	0	1	1	0	0
$y_t - y_{t-1}$	1E-06	0.25	51	75			1		0	0	1	1	0	0
$y_t - y_{t-1}$	0.25	0.5	51	75			1		0	0	1	1	0	0
$y_t - y_{t-1}$	0.5	0.75	51	75			1		0	0	1	1	0	0
$y_t - y_{t-1}$	0.75	1	51	75			1		0	0	1	1	0	0
$y_t - y_{t-1}$	1		51	75			1		0	0	1	1	0	0

Formal to Formal: Denotes individuals employed in the formal sector for two consecutive periods. Other employment transitions are defined similarly.
$y_t - y_{t-1}$: First-difference in annual earnings (in millions of Chilean Pesos)
Fem.: Female gender.
LFP (Lag. LFP): Labor Force Participation in the current year (previous year).
FLFP (Lag. Fo.): Formal employment in the current year (previous year).
Moments are defined by an outcome variable and bounds (columns - and +) on that outcome variable and on conditioning variables. For example, the first moment corresponds to the fraction of individuals who remained in the formal sector among women aged 51 to 75, who were formally employed in the previous year.

Table B2: List of moments: Transitions

Outcome			Conditions					
			Age		Mar.		Fem.	
	-	+	-	+	-	+	-	+
Household Assets	0	0.1	51	55	1	1		
Household Assets	0	0.1	56	61	1	1		
Household Assets	0	0.1	61	66	1	1		
Household Assets	0	0.1	51	55	0	0	1	1
Household Assets	0	0.1	56	61	0	0	1	1
Household Assets	0	0.1	61	66	0	0	1	1
Household Assets	0	0.1	51	55	0	0	0	0
Household Assets	0	0.1	56	61	0	0	0	0
Household Assets	0	0.1	61	66	0	0	0	0
Household Assets	0.1	5	51	55	1	1		
Household Assets	0.1	5	56	61	1	1		
Household Assets	0.1	5	61	66	1	1		
Household Assets	0.1	5	51	55	0	0	1	1
Household Assets	0.1	5	56	61	0	0	1	1
Household Assets	0.1	5	61	66	0	0	1	1
Household Assets	0.1	5	51	55	0	0	0	0
Household Assets	0.1	5	56	61	0	0	0	0
Household Assets	0.1	5	61	66	0	0	0	0
Household Assets	5	10	51	55	1	1		
Household Assets	5	10	56	61	1	1		
Household Assets	5	10	61	66	1	1		
Household Assets	5	10	51	55	0	0	1	1
Household Assets	5	10	56	61	0	0	1	1
Household Assets	5	10	61	66	0	0	1	1
Household Assets	5	10	51	55	0	0	0	0
Household Assets	5	10	56	61	0	0	0	0
Household Assets	5	10	61	66	0	0	0	0
Household Assets	10		51	55	1	1		
Household Assets	10		56	61	1	1		
Household Assets	10		61	66	1	1		
Household Assets	10		51	55	0	0	1	1
Household Assets	10		56	61	0	0	1	1
Household Assets	10		61	66	0	0	1	1
Household Assets	10		51	55	0	0	0	0
Household Assets	10		56	61	0	0	0	0
Household Assets	10		61	66	0	0	0	0

Household Assets: Value of assets owned by the household, excluding the value of pension accounts, in millions of Chilean Pesos.
Mar.: Married or cohabiting.
Fem.: Female gender.
Moments are defined by an outcome variable and bounds (columns - and +) on that outcome variable and on conditioning variables. For example, the first moment corresponds to the fraction of households owning less than 100,000 Chilean Pesos among married or cohabiting couples in which the wife was aged 51 to 55.

Table B3: List of moments: Household Assets

Outcome	Conditions													
	Age		Fem.		Sch.		XP		Cohort		LFP		FLFP	
	-	+	-	+	-	+	-	+	-	+	-	+	-	+
Mean earnings	51	75	0	0	0	7	0	25			1		1	1
Mean earnings	51	75	0	0	0	7	25.5				1		1	1
Mean earnings	51	75	0	0	8	11	0	25			1		1	1
Mean earnings	51	75	0	0	8	11	25.5				1		1	1
Mean earnings	51	75	0	0	12	15	0	25			1		1	1
Mean earnings	51	75	0	0	12	15	25.5				1		1	1
Mean earnings	51	75	0	0	16		0				1		1	1
Mean earnings	51	75	0	0	16		0				1		1	1
Mean earnings	51	75	0	0	0	7	0	25			1		0	0
Mean earnings	51	75	0	0	0	7	25.5				1		0	0
Mean earnings	51	75	0	0	8	11	0	25			1		0	0
Mean earnings	51	75	0	0	8	11	25.5				1		0	0
Mean earnings	51	75	0	0	12	15	0	25			1		0	0
Mean earnings	51	75	0	0	12	15	25.5				1		0	0
Mean earnings	51	75	0	0	16		0				1		0	0
Mean earnings	51	75	0	0	16		0				1		0	0
Mean earnings	51	75	1	1	0	7	0	15			1		1	1
Mean earnings	51	75	1	1	0	7	15.5				1		1	1
Mean earnings	51	75	1	1	8	11	0	15			1		1	1
Mean earnings	51	75	1	1	8	11	15.5				1		1	1
Mean earnings	51	75	1	1	12	15	0	15			1		1	1
Mean earnings	51	75	1	1	12	15	15.5				1		1	1
Mean earnings	51	75	1	1	16		0				1		1	1
Mean earnings	51	75	1	1	16		0				1		1	1
Mean earnings	51	75	1	1	0	7	0	15			1		0	0
Mean earnings	51	75	1	1	0	7	15.5				1		0	0
Mean earnings	51	75	1	1	8	11	0	15			1		0	0
Mean earnings	51	75	1	1	8	11	15.5				1		0	0
Mean earnings	51	75	1	1	12	15	0	15			1		0	0
Mean earnings	51	75	1	1	12	15	15.5				1		0	0
Mean earnings	51	75	1	1	16		0				1		0	0
Mean earnings	51	75	1	1	16		0				1		0	0
Mean earnings	51	75	0	0	0	11	0	20			1		1	1
Mean earnings	51	75	0	0	0	11	20.5	30			1		1	1
Mean earnings	51	75	0	0	0	11	30.5	40			1		1	1
Mean earnings	51	75	0	0	0	11	40.5				1		1	1
Mean earnings	51	75	0	0	12		0	20			1		1	1
Mean earnings	51	75	0	0	12		20.5	30			1		1	1
Mean earnings	51	75	0	0	12		30.5	40			1		1	1
Mean earnings	51	75	0	0	12		40.5				1		1	1
Mean earnings	51	75	0	0	0	11	0	20			1		0	0
Mean earnings	51	75	0	0	0	11	20.5	30			1		0	0
Mean earnings	51	75	0	0	0	11	30.5	40			1		0	0
Mean earnings	51	75	0	0	0	11	40.5				1		0	0
Mean earnings	51	75	0	0	12		0	20			1		0	0
Mean earnings	51	75	0	0	12		20.5	30			1		0	0
Mean earnings	51	75	0	0	12		30.5	40			1		0	0
Mean earnings	51	75	0	0	12		40.5				1		0	0
Mean earnings	51	75	1	1	0	11	0	10			1		1	1
Mean earnings	51	75	1	1	0	11	10.5	20			1		1	1
Mean earnings	51	75	1	1	0	11	20.5	30			1		1	1
Mean earnings	51	75	1	1	0	11	30.5				1		1	1
Mean earnings	51	75	1	1	12		0	10			1		1	1
Mean earnings	51	75	1	1	12		10.5	20			1		1	1
Mean earnings	51	75	1	1	12		20.5	30			1		1	1
Mean earnings	51	75	1	1	12		30.5				1		1	1
Mean earnings	51	75	1	1	0	11	0	10			1		0	0
Mean earnings	51	75	1	1	0	11	10.5	20			1		0	0
Mean earnings	51	75	1	1	0	11	20.5	30			1		0	0
Mean earnings	51	75	1	1	0	11	30.5				1		0	0
Mean earnings	51	75	1	1	12		0	10			1		0	0
Mean earnings	51	75	1	1	12		10.5	20			1		0	0
Mean earnings	51	75	1	1	12		20.5	30			1		0	0
Mean earnings	51	75	1	1	12		30.5				1		0	0
Mean earnings	51	75								50	1		1	1
Mean earnings	51	75							51	52	1		1	1
Mean earnings	51	75							53		1		1	1
Mean earnings	51	75								50	1		0	0
Mean earnings	51	75							51	52	1		0	0
Mean earnings	51	75							53		1		0	0

Mean earnings: Annual earnings, in millions of Chilean Pesos.
Fem.: Female gender.
Sch.: Years of schooling.
XP: Work experience, in years.
LFP: Labor Force Participation in the current year (previous year).
FLFP: Formal employment in the current year.
Moments are defined by an outcome variable and bounds (columns - and +) on that outcome variable and on conditioning variables. For example, the first moment corresponds to the fraction of households owning less than 100,000 Chilean Pesos among married or cohabiting couples in which the wife was aged 51 to 55.

Table B4: List of moments: Mean Earnings

Outcome			Conditions									
			Age		Fem.		Sch.		LFP		FLFP	
	-	+	-	+	-	+	-	+	-	+	-	+
Earnings		1	51	75	0	0			1		1	1
Earnings	1	2	51	75	0	0			1		1	1
Earnings	2	3	51	75	0	0			1		1	1
Earnings	3	4	51	75	0	0			1		1	1
Earnings	4	5	51	75	0	0			1		1	1
Earnings	5		51	75	0	0			1		1	1
Earnings		1	51	75	0	0			1		0	0
Earnings	1	2	51	75	0	0			1		0	0
Earnings	2	3	51	75	0	0			1		0	0
Earnings	3	4	51	75	0	0			1		0	0
Earnings	4	5	51	75	0	0			1		0	0
Earnings	5		51	75	0	0			1		0	0
Earnings		1	51	75	1	1			1		1	1
Earnings	1	2	51	75	1	1			1		1	1
Earnings	2	3	51	75	1	1			1		1	1
Earnings	3	4	51	75	1	1			1		1	1
Earnings	4	5	51	75	1	1			1		1	1
Earnings	5		51	75	1	1			1		1	1
Earnings		1	51	75	1	1			1		0	0
Earnings	1	2	51	75	1	1			1		0	0
Earnings	2	3	51	75	1	1			1		0	0
Earnings	3	4	51	75	1	1			1		0	0
Earnings	4	5	51	75	1	1			1		0	0
Earnings	5		51	75	1	1			1		0	0
Earnings		1	51	75	0	0	8	11	1		1	1
Earnings	1	2	51	75	0	0	8	11	1		1	1
Earnings	2	3	51	75	0	0	8	11	1		1	1
Earnings	3	4	51	75	0	0	8	11	1		1	1
Earnings	4	5	51	75	0	0	8	11	1		1	1
Earnings	5		51	75	0	0	8	11	1		1	1
Earnings		1	51	75	0	0	8	11	1		0	0
Earnings	1	2	51	75	0	0	8	11	1		0	0
Earnings	2	3	51	75	0	0	8	11	1		0	0
Earnings	3	4	51	75	0	0	8	11	1		0	0
Earnings	4	5	51	75	0	0	8	11	1		0	0
Earnings	5		51	75	0	0	8	11	1		0	0
Earnings		1	51	75	1	1	12	15	1		1	1
Earnings	1	2	51	75	1	1	12	15	1		1	1
Earnings	2	3	51	75	1	1	12	15	1		1	1
Earnings	3	4	51	75	1	1	12	15	1		1	1
Earnings	4	5	51	75	1	1	12	15	1		1	1
Earnings	5		51	75	1	1	12	15	1		1	1
Earnings		1	51	75	1	1	12	15	1		0	0
Earnings	1	2	51	75	1	1	12	15	1		0	0
Earnings	2	3	51	75	1	1	12	15	1		0	0
Earnings	3	4	51	75	1	1	12	15	1		0	0
Earnings	4	5	51	75	1	1	12	15	1		0	0
Earnings	5		51	75	1	1	12	15	1		0	0

Earnings: Annual earnings, in millions of Chilean Pesos.
Fem.: Female gender.
Sch.: Years of schooling.
LFP: Labor Force Participation in the current year (previous year).
FLFP: Formal employment in the current year.
Moments are defined by an outcome variable and bounds (columns - and +) on that outcome variable and on conditioning variables. For example, the first moment corresponds to the fraction of formally employed males, aged 51-75, earning less than one million Chilean Pesos.

Table B5: List of moments: Earnings Dispersion

Name	**Symbol**	**Estimate**	***Std. errors***
Type logit - constant	ρ_0	0.12E+02**	*0.57E+01*
Type logit - constant	ρ_0	0.00E+00	*0.80E+02*
Type logit - constant	ρ_0	0.00E+00	*0.12E+03*
Type logit - constant	ρ_0	0.21E-03	*0.31E+01*
Type logit - schooling (female)	ρ_s^f	-0.14E+00***	*0.37E-01*
Type logit - schooling (female)	ρ_s^f	0.00E+00	*0.13E+02*
Type logit - schooling (female)	ρ_s^f	0.00E+00	*0.11E+02*
Type logit - schooling (female)	ρ_s^f	0.00E+00	*0.28E+04*
Type logit - schooling (male)	ρ_s^m	-0.54E+00***	*0.14E+00*
Type logit - schooling (male)	ρ_s^m	0.40E-01	*0.75E+02*
Type logit - schooling (male)	ρ_s^m	0.49E-01	*0.12E+01*
Type logit - schooling (male)	ρ_s^m	0.13E-01	*0.20E+01*
Type logit - married	ρ_m	-0.12E+02**	*0.60E+01*
Type logit - married	ρ_m	0.50E-01	*0.28E+01*
Type logit - married	ρ_m	0.14E-03	*0.27E+03*
Type logit - cohort	ρ_c	0.92E-03	*0.25E+03*
Type logit - cohort	ρ_c	0.17E-03***	*0.30E-04*

Model parameters are described in section 4

Table B6: Simulated Method of Moments Estimates - Permanent Unobserved Heterogeneity Types Logit

Type	1	2	3	4
Married (%)	17.1	90.7	91.6	92.5
Number of children	2.1	2.7	2.7	2.8
Woman's schooling				
Less than primary (%)	70.0	40.5	41.6	46.0
Primary (%)	15.0	31.4	30.0	29.1
Secondary (%)	11.6	22.2	23.4	20.1
Tertiary (%)	3.4	6.0	5.0	4.7
Man's schooling				
Less than primary (%)	87.9	36.9	38.8	43.7
Primary (%)	5.8	31.4	30.2	29.5
Secondary (%)	5.2	24.3	24.5	21.9
Tertiary (%)	1.1	7.4	6.5	4.9
Woman's LFP (%)	47.1	49.0	32.8	77.5
Man's LFP (%)	50.4	70.5	86.9	75.7

Table entries correspond to average characteristics of simulated households grouped by unobserved heterogeneity type.

Table B7: Permanent Unobserved Heterogeneity Types - Observable correlates

Name	**Symbol**	**Estimate**	***Std. errors***
Constant	α_0	0.450	0.478
Married	α_1	-0.921***	0.241
Number of kids	α_2	-0.788***	0.085
Married*kids	α_3	0.303***	0.093
Schooling	α_4	-0.055***	0.012
Age	α_5	0.150***	0.012

Model parameters are described in section 4

Table B8: Probability of no pregnancy: logistic regression